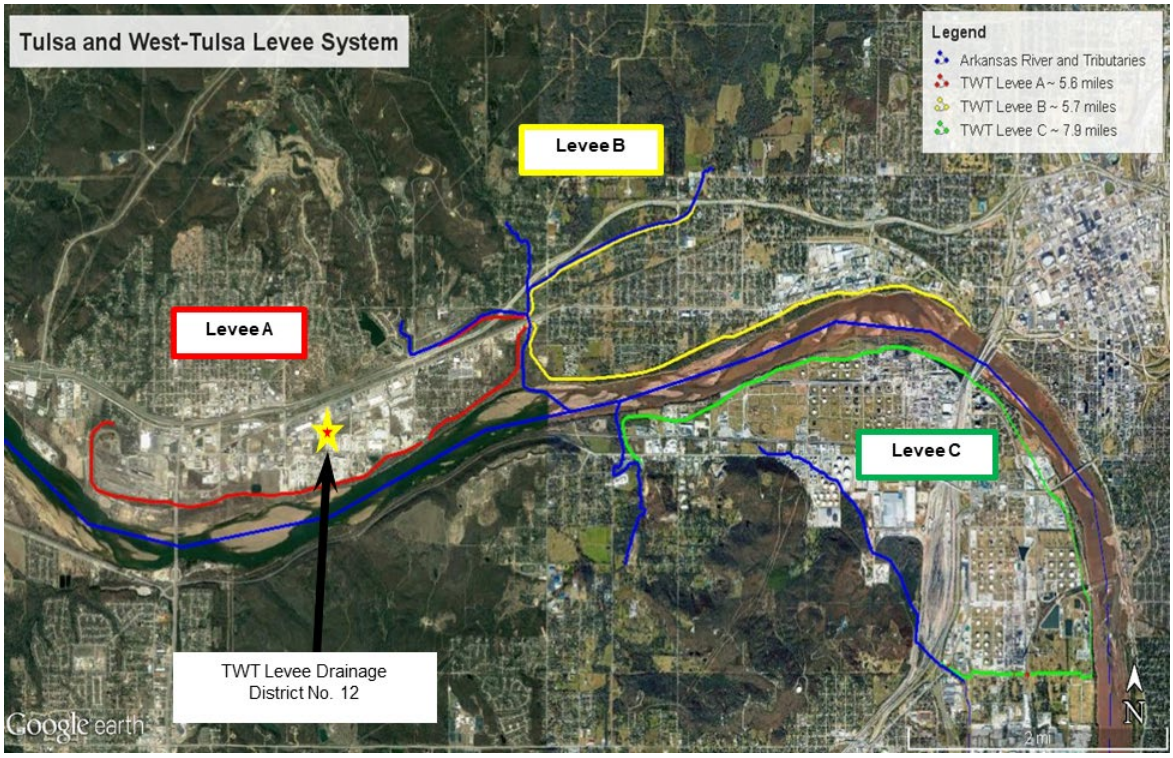
Tulsa and West-Tulsa Levee Feasibility Study

DRAFT REPORT AND ENVIRONMENTAL ASSESSMENT



US Army Corps of Engineers

Southwest Division

Tulsa District

September 2019

US Army Corps of Engineers

Tulsa District

FINDING OF NO SIGNIFICANT IMPACT

TULSA AND WEST-TULSA LEVEES INTEGRATED FEASIBILITY STUDY REPORT AND ENVIRONMENTAL ASSESSMENT - TULSA COUNTY, OKLAHOMA

The U.S. Army Corps of Engineers (USACE), Tulsa District, and the non-Federal sponsor Tulsa County Drainage District No. 12, have conducted an environmental analysis in accordance with the National Environmental Policy Act of 1969, as amended. The draft Integrated Feasibility Report and Environmental Assessment (IFR/EA) dated 16 September 2019, for the Tulsa and West-Tulsa Levee Feasibility Study addresses flood risk to life and property opportunities and feasibility within the Tulsa and West-Tulsa (TWT) Levee System (Levees A, B, and C) in Tulsa County, Oklahoma. The final recommendation will be contained in the report of the Chief of Engineers, in 2020.

The draft IFR/EA, incorporated herein by reference, evaluated various alternatives that would reduce life safety risk from flooding to within Tolerable Risk Guidelines in the study area. The Tentatively Selected Plan was selected based on life safety risk reduction and includes:

- 13 miles of a filtered berm with toe drain
- 2,000 feet of cut off wall in Levee A at the Superfund site
- Filtered floodway structure
- Two detention ponds at Levee B tieback
- 3,000 feet of impervious blanket armoring on landside at overtopping location in Levee B, and
- Reconstruction of pump station 1 through 7 for system-wide effectiveness and completeness
- Implementation of any required environmental compensatory mitigation and associated monitoring and mitigation area adaptive management plan, when applicable and appropriate. Mitigation activities and monitoring and adaptive management will be completed by the managing parties of the mitigation and conservations banks. Mitigation plans are included in Appendix E6
- Conduct bald eagle surveys during PED, develop impact avoidance and minimization plan, obtain take permit, if necessary, all prior to any construction activities.

In addition to a “no action” plan, three alternatives were evaluated. The alternatives included Alternative 1E (Filter Berm with Toe Drain), Alternative 3B (Full Cutoff Wall) and Alternative 5 (Buyout Residential behind Levees A and B). Chapters three and four of the report provide more detail on alternative formulation and plan selection. Non-structural alternatives, in the form of buyouts, were considered but not selected due to the potential for significant, adverse Environmental Justice impacts.

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the Tentatively Selected Plan are listed in Table 1:

Table 1: Summary of Potential Effects of the Tentatively Selected Plan

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
Aesthetics	☒	☐	☐
Air quality	☒	☐	☐
Aquatic resources/wetlands	☐	☒	☐
Invasive species	☐	☐	☒
Fish and wildlife habitat	☒	☐	☐
Threatened/Endangered species/critical habitat	☐	☒	☐
Historic properties	☒	☐	☐
Other cultural resources	☒	☐	☐
Floodplains	☐	☐	☒
Hazardous, toxic & radioactive waste	☒	☐	☐
Hydrology	☐	☐	☒
Land use	☒	☐	☐
Navigation	☐	☐	☒
Noise levels	☒	☐	☐
Public infrastructure	☒	☐	☐
Socio-economics	☐	☐	☒
Environmental justice	☐	☐	☒
Soils	☒	☐	☐
Tribal trust resources	☒	☐	☐
Water quality	☐	☐	☒
Climate change	☒	☐	☐
Bald Eagles	☐	☒	☐

All practicable and appropriate means to avoid or minimize adverse environmental effects were analyzed and incorporated into the Tentatively Selected Plan. Best management practices (BMPs) as detailed in the IFR/EA will be implemented, if appropriate, to minimize impacts. Impacts to private property, infrastructure, and natural areas would be avoided to the maximum extent possible during the construction of the Tentatively Selected Plan by altering the filtered berm design as necessary. Within the detention ponds, the area would be replanted with appropriate native grasses to support native communities. If mowing is needed, it would occur only when needed to maintain the flood risk purpose, and the detention ponds would not be mowed lower than 8 inches to support American Burying Beetle habitat needs. The detention ponds would not be developed or otherwise disturbed. All standard BMPs and requirements for construction near streams and rivers would be followed to ensure no contamination of water occurs. Chapter 5 and Appendix E2 further outline avoidance and minimization measures. A Programmatic Agreement is being developed to survey construction areas, and if discovered, properly account for any historic properties.

The Tentatively Selected Plan will result in unavoidable adverse impacts to 9 acres of American Burying Beetle habitat and 1,833 linear feet of Harlow Creek that will require compensatory mitigation. To mitigate for these unavoidable adverse impacts, the U.S. Army

Corps of Engineers will purchase the necessary amount of credits from a mitigation bank to reduce stream impacts to less than significant. Likewise, the U.S. Army Corps of Engineers will purchase the necessary amount of credits from a conservation bank to reduce American Burying Beetle impacts to less than significant. Appendix E6 contains more details regarding mitigation plans.

While the construction of the Tentatively Selected Plan is not expected to have direct take of bald eagles, construction activities and associated noise could indirectly impact nesting bald eagles.

Public review of the draft IFR/EA and FONSI will be completed on 17 October 2019. All comments submitted during the public review period were responded to in the Final IFR/EA and FONSI.

Pursuant to section 7 of the Endangered Species Act of 1973, as amended, a Biological Assessment was submitted to the U.S. Fish and Wildlife Service (FWS) for their review of impacts to the American Burying Beetle.

In compliance with the Bald and Golden Eagle Protection Act, bald eagle surveys will be conducted during PED to inform and design a construction impact avoidance and minimization plan. This plan will be coordinated with the FWS Oklahoma Ecological Services Office and Southwest Region Migratory Bird Office. If necessary, take permits for bald eagle will be obtained.

All terms and conditions, conservation measures, and reasonable and prudent alternatives and measures resulting from these consultations shall be implemented in order to minimize take of endangered species and avoid jeopardizing the species.

Pursuant to section 106 of the National Historic Preservation Act of 1966, as amended, the U.S. Army Corps of Engineers determined that historic properties may be adversely affected by the Tentatively Selected Plan. The Corps, Tulsa County, Oklahoma SHPO, Muscogee (Creek) Nation, and the Osage Nation will entered into a Programmatic Agreement (PA). All terms and conditions resulting from the agreement shall be implemented in order to minimize adverse impacts to historic properties.

Pursuant to the Clean Water Act of 1972, as amended, the discharge of dredged or fill material associated with the Tentatively Selected Plan has been found to be compliant with section 404(b)(1) Guidelines (40 CFR 230). The Clean Water Act Section 404(b)(1) Guidelines evaluation can be found in the 404(b)1 analysis in Appendix E4 of the IFR/EA.

A water quality certification pursuant to section 401 of the Clean Water Act will be obtained from the Oklahoma Department of Environmental Quality. All conditions of the water quality certification shall be implemented in order to minimize adverse impacts to water quality.

Technical, environmental, life safety, and economic criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.

All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on this report, the reviews by other Federal,

State and local agencies, Tribes, input of the public, and the review by my staff, it is my determination that the Tentatively Selected Plan would not cause significant adverse effects on the quality of the human environment; therefore, preparation of an Environmental Impact Statement is not required.

_____
Date

_____
Scott S. Preston, P.E.
Colonel, Corps of Engineers
Tulsa District Commander

EXECUTIVE SUMMARY

Background

As authorized by Section 1202 of the Water Infrastructure Improvements for the Nation Act (WIIN Act of 2016, Public Law 114-322), the study is an integrated feasibility report and environmental assessment completed by the U.S. Army Corps of Engineers (USACE), Tulsa District (SWT). USACE constructed the Tulsa and West-Tulsa (TWT) levee system in the mid-1940s as authorized in the 1941 Flood Control Act to protect residential and industrial property from frequent flooding along the Arkansas River and associated tributaries in Tulsa and Sand Springs (a suburb of Tulsa). Levees A, B, and C were completed in 1945 for a total of 20 miles of earthen levees on the left and right bank of the Arkansas River.

The TWT levee system is located in northeast Oklahoma, Tulsa County, and extends from the City of Sand Springs downstream along the Arkansas River into the City of Tulsa. Upstream, there are a series of USACE flood control dams. Keystone Dam is about 8 miles upstream, and flood discharges from Keystone have direct and substantial impacts to the levee system. Kaw Dam is about 100 miles upstream of Keystone (Figure ES-1).

Non Federal Sponsor

After the TWT levee system was completed in 1945, the Tulsa County Drainage District No. 12 (Levee District) assumed ownership and is the local non-federal sponsor responsible for operating and maintaining the levees; however, the levee system still remains in the USACE portfolio and is eligible for rehabilitation assistance under Public Law (P.L.) 84-99 following flood or storm damage under the System Wide Improvement Framework (SWIF) Program.

Problems and Opportunities

The problem addressed in this report is flood risk to life and property in communities behind the TWT levee system. The TWT levee system could fail due to overtopping and inadequately controlled under-seepage and through seepage.[1] As the TWT levee system features continue to degrade as a result of flood events, the systems' ability to operate as originally designed diminishes. If no action is taken, under and through seepage problems will worsen and pose a threat to the integrity of the levee while further degradation to pumping stations and appurtenant works could cause interior flooding that can impact industries, infrastructure and interrupt the transportation system. Given the problem, there is an opportunity to identify a long-term cost

[1] Under seepage and through seepage is river water that flows under and through a levee from a river during a flood. Generally, the water seeps through the levee where seepage reduction measures such as relief wells and toe drains are put in place to reduce water pressure and allow excess water to divert safely. Otherwise, water flows through the soil towards the dry side of the levee and erodes levee or foundation materials resulting in sand boils that can destroy a levee if not addressed.

effective and environmentally sustainable solution to reduce life safety risks and risk of damages due to levee breach and non-breach flooding.

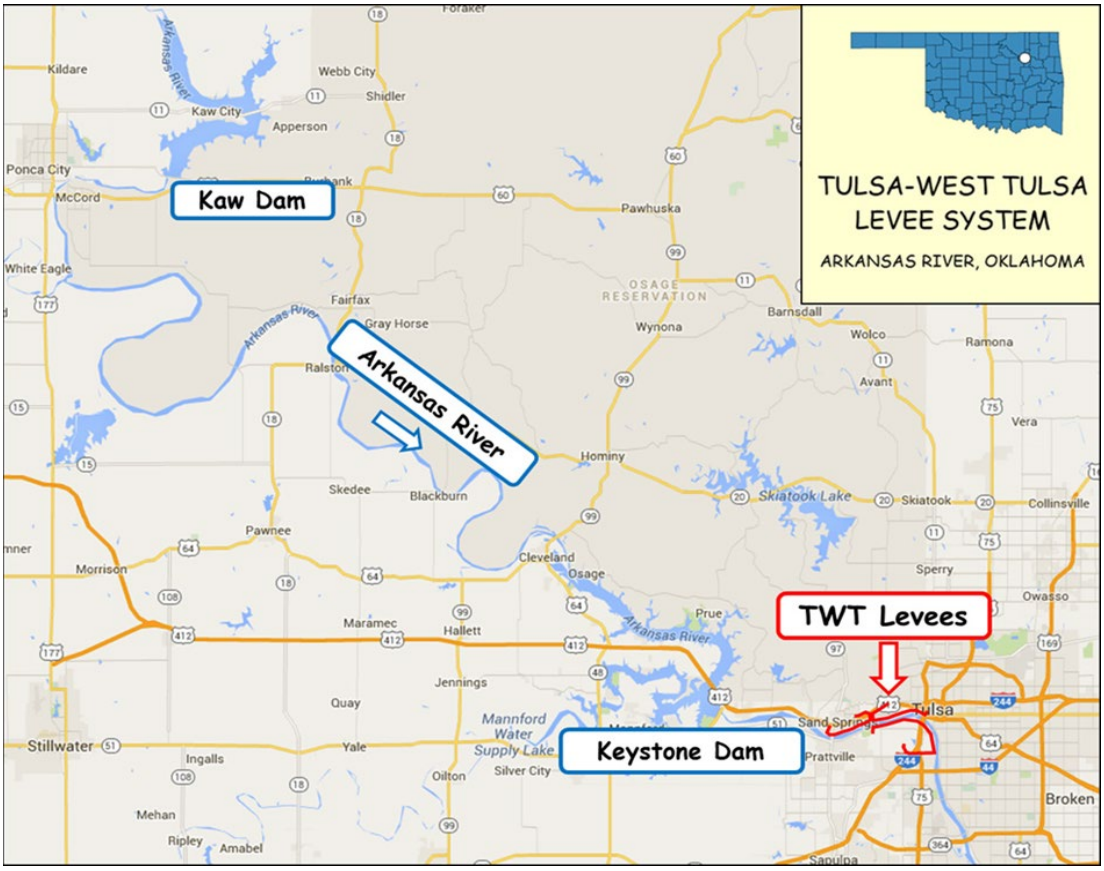


Figure ES-1: Tulsa West Tulsa Levee - Area Map

Alternative Formulation and Plan Comparison

Plan Formulation Objectives

The overarching objective is to find an effective and environmentally acceptable solution to ensure a sustainable and resilient levee system, which reduces risk of damages and life safety. Each planning objective applies to the study area for the 50-year period of analysis (2024 to 2074). Specific objectives are to:

- Reduce life safety risk, and
- Reduce property damages.

Per draft Engineer Circular (EC) 1165-2-218 (*Levee Safety Program Policy and Procedures*), the Project Delivery Team (PDT) used tolerable risk guidelines (TRG) for the TWT levee system evaluation, throughout the study including problem identification and study objectives,

developing and evaluating alternatives, and recommending a plan for implementation. Per Planning Bulletin 2019-04 (*Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies dated June 20, 2019*), guidance requires that at a minimum, one alternative must address TRG 1 and TRG 4 and be identified.

TRG 1 was the primary focus during plan formulation because it establishes a threshold for life safety risk tolerability. The PDT applied this standard only to the risks associated with under and through seepage (prior to overtopping risk). Life loss due to breach prior to overtopping drives the risk although the frequency of overtopping plots higher.

After life safety risk, economic and environmental risks were assessed to determine how they influenced meeting TRG1 for risks prior to overtopping. TRG 4 specifies that entities responsible for managing risks associated with a levee system continue to reduce risks as much as possible.

Formulation focused geographically on system Levee A and Levee B, and selection of the tentatively selected plan (TSP) was based on reduced risks for life safety versus National Economic Development (NED) benefits as explained below.[2] In terms of geographic focus, USACE completed a Semi-Quantitative Risk Assessment (SQRA) for the TWT levee system in 2016 and 2017 and for this study in 2019. SQRAs evaluate a range of flood events and identify potential modes of failure in a levee system, and estimate resulting life loss and property damage for each failure mode. Based on the 2019 SQRA, Levee A and Levee B were evaluated as a high risk of failure and life loss. In contrast, Levee C was assigned a low risk of life loss given that estimated floods depths were comparatively small (i.e., 2 to 4 feet) and there was no estimated life loss, when compared to Levee A and Levee B where depths were well above first story elevations associated with life safety risk.

With respect to NED versus life safety, the preliminary set of management measures and plans and the final array of alternatives were evaluated using standard USACE methods and models based both on NED benefits and life safety risk reduction benefits. However, given that the probability associated with inundation and damages to property behind the levees in the floodplain are relatively low, the estimated costs of alternatives are higher than estimated property damages. Therefore, the NED plan is the without project alternative. In contrast,

[2] This team has requested an exception from requirements to recommend an NED plan and seek approval of the tentatively selected plan based on life safety risks rather than monetized benefits. The federal Principles and Guidelines (P&G) state, "*A plan recommending Federal action is to be the alternative plan with the greatest net economic benefit consistent with protecting the Nation's environment (the NED plan), unless the Secretary of a department or head of an independent agency grants an exception to this rule*." Exceptions may be made when there are overriding reasons for recommending another plan, based on other Federal, State, local and international concerns.

evaluation of alternatives based on life safety benefits show that several provided significant reductions in life safety risk.

Originally, many alternatives initially included an increase in the level of protection along the main stem levee to a 0.2 percent ACE (1/500 ACE) flood along the Arkansas River. This level of protection corresponded to a discharge of 490,000 cubic feet per second (cfs). A scenario was developed in the HEC-RAS model that took the October 1986 release hydrograph from Keystone Dam and scaled all of the ordinates so that the peak discharge matched the 0.2 percent ACE flood. The geometry of the HEC-RAS model was modified so that the “bump outs” constructed within the Arkansas River as part of the development of The Gathering Place were considered. The Gathering Place is a public open space centered on the east bank of the Arkansas River along Riverside Drive approximately two miles south of downtown Tulsa and adjacent to the Maple Ridge historic district, an upscale residential area. This public-private partnership covers approximately 100 acres of land and cost about $465 million to construct. This transfer of risk was not trivial (with increases in flood inundation depths of 2-5 feet), and it affects both residential areas and public use areas with significant levels of financial investment. Therefore, the transfer of risk posed by the adoption of the 0.2 percent ACE was deemed unacceptable by the PDT, and after consultation with the local sponsor, raising the levee was screened out from further analysis.

After screening the initial array of six alternatives that incorporated permutations of management measures such as filter berms with toe drain and cutoff walls, the PDT selected four final alternatives:

- Alternative 1E (filter berm with toe drain);
- Alternative 3B (full cutoff wall);
- Alternative 5 (buyout of residential properties behind Levee A and B); and,
- Alternative 6 (no action).

Final Array of Alternatives were evaluated based on life safety benefits. The probability associated with inundation of investments in the floodplain are relatively low, the cost of each alternative exceeded the potential reduction in property damages. However, when evaluating each alternative based on life safety benefits several alternatives provided significant reduction in life safety risk.

Alternative 5 (residential property buyout) reduces the probability of life loss to zero, and whether the levee fails or not has no bearing on the number of lives lost. Alternative 1 through 3 are structural solutions that involve changes to the levees themselves, and each reduces annual probability of levee failure by improving geotechnical aspects of the levees; there is still some level of risk albeit very small.

In addition to life safety risks, the final array of alternatives were evaluated based on:

- Cost effectiveness;
- Flood damages;
- TRG 1;
- TRG 4;
- Real estate impacts; and,
- Environmental criteria.

Table ES-1 summarizes the results of this evaluation. All three alternatives fully met TRG 4; however, only Alternative 5 fully met TRG 1. Overtopping risk was addressed by providing an armored landside section along Levee B but does not lower the associated risk below TRG. The PDT evaluated what it would take to lower overtopping below TRG, but it was significant and would not be justifiable.

Alternative 3B and 5 had high impacts to real estate, the environment, and cultural resources. High impacts to the environment and cultural resources were defined by the PDT as impacts that are significant enough to be challenging and costly to mitigate, and would warrant an Environmental Impact Statement (EIS). Alternative 3B was evaluated to have high impacts, as construction would require the levee to extend outside the existing footprint. Alternative 5 was evaluated to have high impacts based on environmental justice issues.

Alternative 3 generated an additional one-half order of magnitude reduction in risk, but at a cost three times that of Alternative 1, which still partially met TRG 1 and fully met TRG 4. Therefore, the team recommended Alternative 1E as the tentatively selected plan.

Table ES-1: Evaluation of Final Array of Alternatives

Alternative	Total Cost [1]	Order of Magnitude Risk Reduction	TRG 1 (F/P/N) [2]	TRG 4 (F/P/N) [2]	Real Estate Impacts (L/M/H)	Environmental Impacts (L/M/H)
Alternative 1E (Filter Berm with Toe Drain)	$ 160M	2	P	F	Low to Medium	Low
Alternative 3B (Full Cutoff Wall)	$ 390M	2.5	P	F	High	High
Alternative 5 (Buyout)	$ 200M to $400M	3.0	F	F	High	High

1 - Cost is a Class 4 cost estimate. Construction cost only; does not include real estate; environmental mitigation; no utility relocation or removal; no S&A costs; etc.

2 - TRG 1 or 4 - Fully met (F); partially met (P); and Not met (N)

Environmental Assessment

The construction of the TSP would result in the temporary impact of 9 acres of American Burying Beetle (Federally endangered) habitat, and the semi-permanent loss of 1,833 feet stream habitat along Harlow Creek. In addition, bald eagles (federally protected) roost, nest, and forage along the Arkansas River that runs parallel to Levees A, B, and C. While the construction of the TSP is not expected to have direct take of bald eagles, construction activities and associated noise could indirectly impact nesting bald eagles.

Historic properties may exist and have the potential to be adversely impacted during construction. All practicable impact avoidance measures and BMPs will be utilized to avoid and minimize adverse impacts to the environment and historic properties. Unavoidable impacts to habitat, Federally threatened and endangered species, and known and unknown historic properties are accounted for in the mitigation plan to reduce impacts to less than significant.

Recommended Plan

Based on the comparison of these plans, the TSP is Alternative 1E (Filtered Berm with Toe Drains on Levee A and Levee B and reconstruction of Pump Station Nos. 1 through 7). This plan meets study objectives of reducing flood risk and flood damages, reducing flood risk to public health, safety and life, and minimizes residual flood risks to the extent justified. Alternative 1E is the Preferred Alternative based primarily on life safety. Environmental and cultural resources, as well as public input and costs, were also considered as part of the NEPA process. Structural features of Alternative 1E include:

- 13 miles of a filtered berm with toe drain;
- 3,000 feet of cut off wall in Levee A at the Superfund site;
- Filtered floodway structure;
- Two detention ponds at Levee B tieback;
- Impervious blanket armoring on landside at overtopping in Levee B; and,
- Reconstruction of pump station 1 through 7 for system-wide effectiveness and completeness.

The Total Project First Cost for the TSP is $159,688,000. Total average annual costs for the TSP is $6.8M (Federal discount rate of 2.875%, 50 year period of analysis).

Recommendations for addressing residual risk by the non-Federal sponsor include nonstructural features, such as comprehensive flood warning emergency evacuation planning and floodplain management. Specifics of these plans will be included in the language of the Project Partnership Agreement executed between the USACE and non-Federal sponsor.

Tulsa County is the anticipated funding source for the project implementation phases. Tulsa County will be required to obtain the required lands, easements, rights-of-way, relocations, and disposal areas (LERRD) in order to implement the project. This includes the lands required for the filtered berms, cutoff wall, impervious blankets, and detention ponds.

Reconstruction of the system with the Levee District under the USACE existing cost share requirements would permit the entire system to be determined to be evaluated and entail a full disclosure of future operation, maintenance, repair, replacement and rehabilitation (OMRR&R) requirements for all components of the levee system. This comprehensive action would allow the entire system to become the responsibility under current standards of the non-Federal sponsor following completion and turn-over of the reconstructed system. This situation would allow receipt from the non-Federal sponsor of the assurances required to qualify under current criteria as a non-Federal sponsor, eliminating any future confusion regarding requirements for OMRR&R.

The mitigation plan entails:

- Purchase the necessary amount of credits from a stream mitigation bank to reduce stream impacts to less than significant.
- Purchase the necessary amount of credits from an American Burying Beetle conservation bank to reduce American Burying Beetle impacts to less than significant.
- Conduct bald eagle surveys during PED, develop impact avoidance and minimization plan, obtain take permit if necessary all prior to any construction activities.
- A Programmatic Agreement would be executed between USACE, Tulsa County Drainage District No. 12 (the implementation sponsor), Oklahoma State Historic Preservation Officer (SHPO), Muscogee (Creek) Nation and the Osage Nation tribes to account for impacts to known and unknown historic properties.

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CHAPTER 1: INTRODUCTION

1.1 Purpose & Need

The purpose of the study is to investigate the feasibility of improving the resiliency of the existing Tulsa and West-Tulsa (TWT) levee system by reducing risk to life and damages to property in portions of Tulsa County and the City of Tulsa behind the levee system. U.S. Army Corps of Engineers (USACE) constructed the TWT levee system in the mid-1940s as authorized in the 1941 Flood Control Act to protect residential and industrial property from frequent flooding along the Arkansas River and associated tributaries in Tulsa and Sand Springs (a suburb of Tulsa). Levees A, B, and C were completed in 1945 for a total of 20 miles of earthen levees on the left and right bank of the Arkansas River. Levees A, B, and C are separable elements (see Figure 1-1). However, although Levees A and B are separate segments, they are connected hydrologically at the floodway structure along Charles Page Boulevard where Bigheart Creek enters the Arkansas River.

Several flood events have occurred along the Arkansas River in Tulsa County. Before construction of Keystone Dam, the flood of record occurred in October 1959 with an estimated peak flow of 246,000 cubic feet per second (cfs). The second largest pre-regulation flood was 244,000 cfs in June 1923. Since the construction of Keystone Dam, significant flood-control releases took place in: 1974, 1986, 1993, 1998, 2007, and 2019, and the largest were in October 1986 with peak flows of 307,000 cfs and May 2019 with peak flows of 277,000 cfs.

The study or impact area is home to a substantial population of elderly and low income residents, and flood evacuation has historically proved to be more of a hurdle for this demographic for a number of reasons. For example, flood warnings may not be as effective because of physical and medical constraints on the part of residents, or due to a lack of technology to receive warnings such as mobile devices with text messaging. Another reason is that some may be reluctant to leave because of possible mistrust of public officials regarding the severity of the threat, or for fear of their personal property being stolen after they leave.

Study modeling using HEC-LifeSim indicates that within eight hours of receiving flood warnings, 81 percent of the population behind the levees would evacuate. If warning times were shorter or if fewer people evacuated, the number of casualties would likely rise dramatically. For example, the estimated number of fatalities triples when the model assumes a 75 percent evacuation rate after 24 hours (see Economic Appendix C for details on demographics).

Any catastrophic failure of TWT levees would pose significant public health and environmental concerns. Since the early 1900s, areas behind the levee system have been home to large concentrations of heavy industry such as the Sand Springs Petrochemical Complex (Superfund site) and the Sheffield Steel Corporation behind Levee A, both of which house hazardous materials and have reported hazardous material releases in the past. Breach or overtopping of the Levee A and Levee B system could release hazardous materials from the Sand Springs Superfund site, or from one of the many industrial facilities behind the levee system. In the event of a release, hazardous materials could enter the Arkansas River and affect downstream communities and wildlife habitats.

Heavy industry also exists behind Levee C including Westside Chemical Co., Ozark Fluorine Specialties Inc., Koch Industries, Holly Frontier Corporation Tulsa Refinery, and the Public Service Company of Oklahoma (PSO). These industrial locations house hazardous materials. As in Levee A and Levee B, there have been reported hazardous material releases. In addition, a breach or overtopping of Levee C could result in the release of hazardous materials from one of the many industrial facilities behind the levee.

1.2 Study Authority

This Study is authorized under Section 1202 of the Water Infrastructure Improvements for the Nation Act (WIIN Act of 2016, Public Law 114-322), which states:

"(a) Tulsa and West Tulsa, Arkansas River, Oklahoma.—

(1) In general.--The Secretary shall conduct a study to determine the feasibility of modifying the projects for flood risk management, Tulsa and West Tulsa, Oklahoma, authorized by section 3 of the Act of August 18, 1941 (55 Stat. 645, chapter 377).

(2) Requirements.--In carrying out the study under paragraph (1), the Secretary shall address project deficiencies, uncertainties, and significant data gaps, including material, construction, and subsurface, which render the project at risk of overtopping, breaching, or system failure."

1.3 Study Location

The TWT levee system is located in northeast Oklahoma in Tulsa County (Figure 1-1). The levee system extends from the City of Sand Springs downstream along the Arkansas River into the City of Tulsa. Levees A and B are on the left bank of the river and extend from river mile (RM) 531.1 to RM 524.1. Levee C spans from RM 526.7 to RM 521.3 on the right bank. Upstream of the levee system, there are a series of USACE flood control dams. Keystone Dam is approximately 8 miles upstream of Tulsa, and flood discharges from Keystone have direct and substantial impacts to the TWT levee system. Kaw Dam is about 100 miles upstream of Keystone (Figure 1-2).

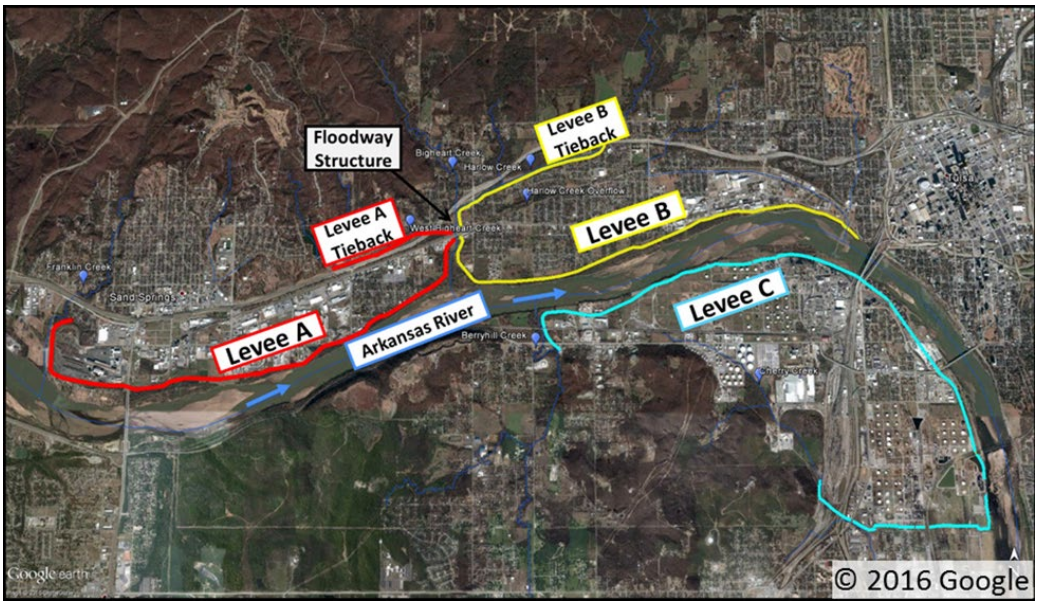

Figure 1-1: TWT Levee System Aerial Photograph (Map Imagery © Google 2016)

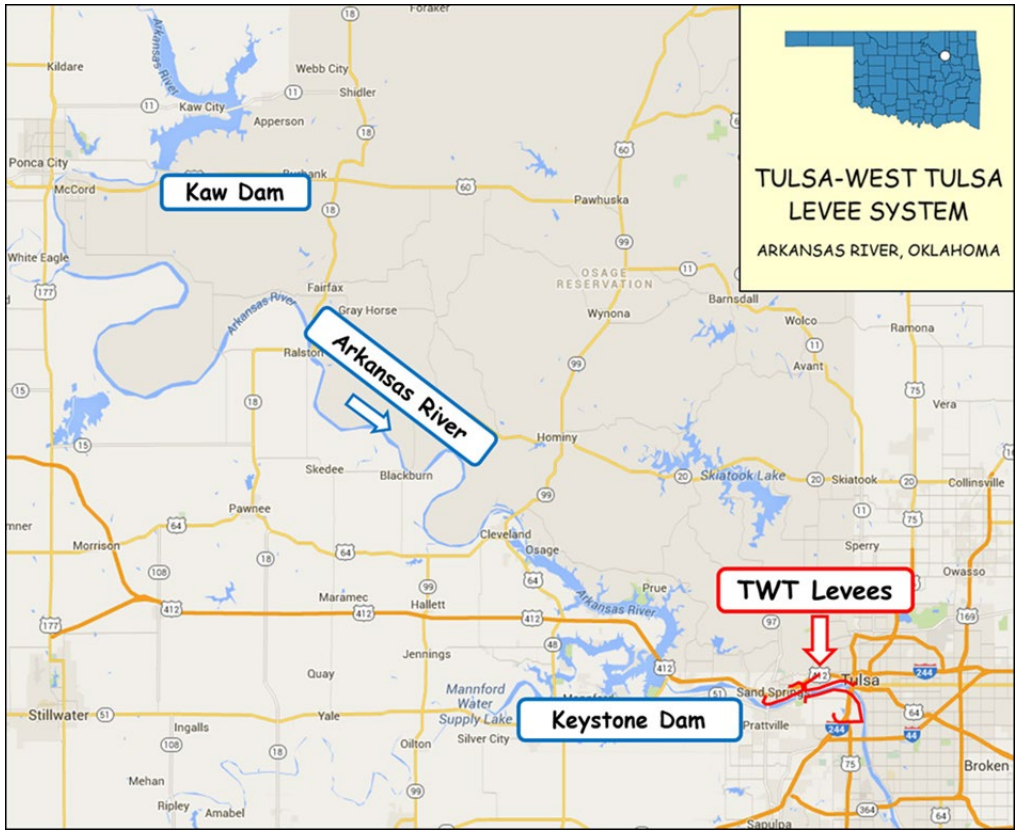

Figure 1-2: Location of TWT Levees & USACE Dams (Map Imagery Google 2016)

1.4 Non-Federal Sponsor

After the levee system was completed in 1945, the Tulsa County Drainage District No. 12 (Levee District) assumed ownership and is the local sponsor responsible for operating and maintaining the levees. However, TWT levee system still remains in the USACE portfolio and a System Wide Improvement Framework (SWIF) is currently in place to govern system maintenance. The Levee District Letter of Intent and Self Certification of Financial Capability, dated September 7, 2018, states their willingness and their ability to cost share in implementing the project. The Feasibility Cost Share Agreement (FCSA) between the USACE and the Levee District was executed on September 28, 2018.

1.5 Scope

This study evaluated upstream and downstream effects of existing conditions; however, it focuses only on areas behind the TWT levee system.

1.6 Overview of Levee & Structures

Levee A begins in Sand Springs approximately a half mile west of the intersection of Highway 51 and the Sand Springs Expressway. The levee follows Franklin Creek south to its confluence with the Arkansas River where it then follows the left bank for nearly three and a half miles downstream. At the confluence of the Arkansas River and Bigheart Creek, the levee heads north along the creek until it terminates at the Charles Page Boulevard floodway structure. The tieback section of Levee A begins on the upstream side of the floodway structure and follows West Bigheart Creek back to the west, crosses under the Sand Springs Expressway, then parallels the expressway and terminates 0.9 miles west.

Levee A is about 5.6 miles long, and features a 260-foot long gravity-type floodwall, three pump stations to pass stormwater to the Arkansas River, and numerous encroachments and pipe penetrations through the levee embankment (Table 1-1 and Figure 1-3).

Table 1-1: Summary of Levee A Features

Feature	Description
Length	5.6 miles, crest elevation varies along its length from elevation 663.5 feet to 656.5 feet.
Embankment Description	Earthen levee with 2.5H:1V landside and 3H:1V riverside slopes, 8-foot crest width, typically sandy silt and silty sand, pervious sand fill shell on the landside slope.
Embankment Height	Average 15-feet high, varies up to a maximum height of 22.5-feet near pump station 3.
Structures	One 260-foot long section of gravity-type floodwall structure wing walls.
Closure Structures	None (automatic flap gates on pipe penetrations not considered)
Pump Stations (PSs)	Three pump stations (1, 2, 3) with ponding areas provided at stations 1 and 3.
Major Encroachments/ Adjacent Construction	About 80 pipe penetrations, several industrial sites adjacent to levee, Hwy 97 bridge, a Petrochemical Superfund Site, the Sand Springs wastewater treatment plant, the Sand Springs Expressway, and the 81st West Avenue box culvert.

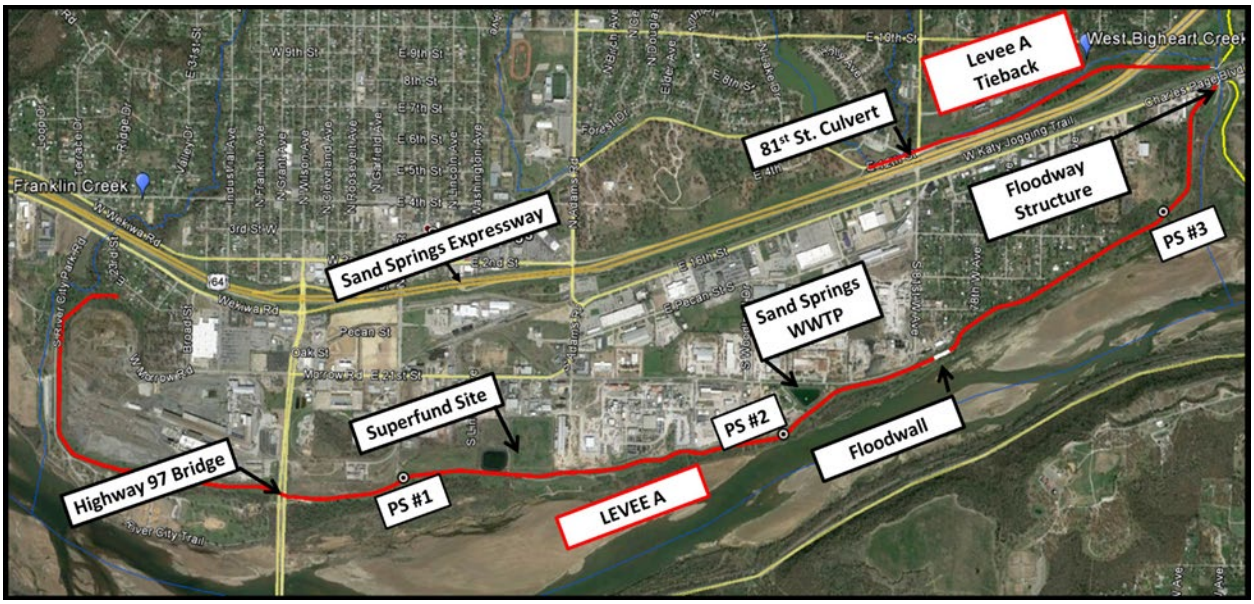

Figure 1-3: Levee A Major Features and Encroachments (Imagery ©Google 2015)

Levee B is on the left bank of the Arkansas River downstream of Levee A. The Levee B tieback embankment begins near the intersection of the Sand Springs Expressway and 49th West Avenue then parallels the Harlow Creek diversion channel for about 1.7 miles southwest until tying into the floodway structure wing walls at Charles Page Boulevard. The mainstem Levee B embankment begins on the downstream side of the floodway structure and follows Bigheart Creek until its confluence with the Arkansas, and then parallels the left bank of the Arkansas for 3.5 miles before terminating at the rail line just upstream of I-244. The approximate combined length of Levee B is 5.8 miles. The levee features two pump stations constructed as a part of the original project, and two additional pump stations constructed by the City of Tulsa. Similar to Levee A, there are numerous encroachments and pipe penetrations along Levee B (Table 1-2 and Figure 1-4).

Table 1-2: Levee B Summary of Features

Feature	Description
Length	5.8 miles, crest elevation varies along its length from elevation 658.5 feet to 647.8 feet
Embankment Description	Earthen levee with 2.5H:1V landside and 3H:1V riverside slopes, typically sandy silt and silty sand. Pervious sand fill shell on the landside slope with 8- foot crest width.
Embankment Height	Average 18-feet high, varies up to a maximum height of 28-feet near the Charles Page Boulevard floodway structure.
Structures	Ties into floodway structure wing walls at Charles Page Boulevard.
Closure Structures	None (Automatic flap gates on pipe penetrations not considered)
Pump Stations	Two pump stations (4 and 5) with a ponding area provided at station 4. Two additional City of Tulsa pump stations (Mayfair and the Vern)
Major Encroachments/ Adjacent Construction	Approximately 95 pipe penetrations through embankment; industrial sites adjacent to Levee B; three road crossings along the tieback levee at 49th West Avenue, 65th West Avenue, and 7th Street West; Parkview Drainage Channel on levee interior.

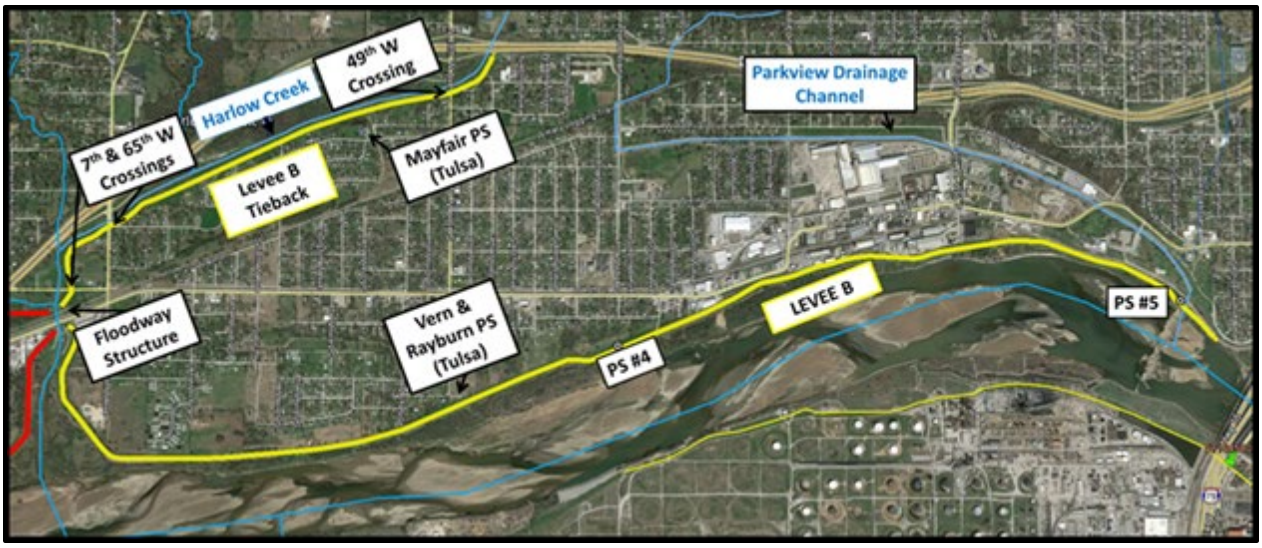

Figure 1-4: Levee B Major Features (Imagery ©Google 2015)

Levee C was built on the west bank, or right bank, of the Arkansas River and extends for 7.9 miles along the river and Berryhill and Cherry Creeks. On the upstream end, the levee begins near Berryhill Creek and West 21st Street, and provides protection from the creek for roughly 0.5 miles before it converges with the Arkansas. The levee then parallels the river another 5.5 miles around the bend where the river begins to head south in Tulsa. Just south of the Public Service Company of Oklahoma (PSO) generating station property the levee goes west towards Interstate 244 for about two miles where it provides protection from Cherry Creek .The levee then heads north and terminates beside the rail yard (Table 1-3 and Figure 1-5).

Table 1-3: Levee C Summary of Features

Feature	Description
Length	7.9 miles, crest elevation varies from elevation 656 feet to 647.5 feet.
Embankment Description	Earthen levee with 2.5H:1V landside and 3H:1V riverside slopes, 8-foot crest width, maximum height of 26-feet, average height of 11.4-feet, typically sandy silt and silty sand, pervious sand fill shell on landside slope.
Structures	170-foot section of T-type floodwall ties into the PSO intake well wall, a small T-type floodwall also exists at closure structure 4.
Closure Structures	Originally six stop-log structures constructed, two additional closures constructed in 1956 by PSO and 1972 by Texaco; closure 2, 3 and 5 are permanently closed. Sandbag closure on Southwest Boulevard (automatic flap gates on pipe penetrations not considered).
Pump Stations	Pump stations 6 and 7
Major Encroachments/ Adjacent Construction	Approximately 170 pipe penetrations, road and railroad crossings; heavy industry and refineries adjacent to levee, stormwater ponds; Westport Apartments, River Park Trail and River West Festival Park on top of levee; stream bank protection, environmental remediation I- 244 corridor bridge cluster.

Figure 1-5: Levee C Major Features

1.6.1 History of Repairs to Levee & Structures

Over the past 30 years, the Levee District has allocated approximately 20 percent of its annual budget towards Operations and Maintenance (O&M) of the TWT levee system. As with many aging levee systems, the O&M Manual does not include the Repair, Replacement and Rehabilitation (RR&R) requirements of the TWT levee system. TWT levee system has 11 miles of antiquated vitrified clay pipe toe-drains and obsolete pump station components that do not meet contemporary design standards for safety and reliability. USACE Silver Jackets Team and the Levee District have partnered on projects to undertake a cooperative approach to increase community understanding of risks associated with the levee through a Risk Informed Community Outreach project. This has resulted in additional tax revenue for the levee system, and since 2009 the District has completed over $450,000 in repairs. All known modifications and repairs as well as the year(s) performed are listed below.

Levee A Modifications and Repairs

- Relief Well Installation (1944)
- Streambank Protection (1960)
- Flood Repairs (1984)
- Flood Repairs (1987)
- Drainage Structure Repairs (1993-2002)
- West Bigheart Creek Channel Erosion Repair (1996)

Levee B Modifications and Repairs

- Bank Stabilization (1959)
- Flood Repairs (1984)
- Flood Repairs (1987)
- Drainage Structure Repairs (1993-2002)
- Streambank Protection (1996)

Levee C Modifications and Repairs

- Stop Log Structure Modifications (1956-1990)
- Constructed a Storm Surge Pond at Refinery (1972)
- Stop Log Structure No. 3 Repair (Repair from 1986 flood in 1988)
- Drainage Structure Repairs (1993-2002)
- Environmental Remediation Actions at Refinery (1994)
- River Parks West Trail was constructed (2000)
- PSO constructed a kayak wave park (2004)
- Streambank Protection (Unknown)

1.6.2 Semi-Quantitative Risk Assessment (SQRA) 2016-2017

The TWT Study is the result of a SQRA completed for TWT levee system in 2016 and 2017. A SQRA is a higher-level risk assessment based on a range of events (flood, rainfall, inundation) that assesses potential modes of failure in a levee system and resulting consequences including life loss and economic damages. The TWT SQRA assigned a risk category of “Very High” to levees A and B and a risk category of “High” to Levee C. Risk characterizations are based on two factors, likelihood of levee failure and resulting life loss. The SQRA team concluded that the likelihood of levee failure from overtopping and internal erosion was Very High and also characterized life loss estimates from a breach as Very High. More details about the SQRA can be found in the SQRA Summary Appendix D.

1.6.3 2019 SQRA Performed in this Study

The Southwestern Division Cadre, Risk Management Center (RMC), Southwest Tulsa District (SWT), and local levee district representatives met during March 2019 to update the SQRA. The 2019 SQRA assessed Tulsa County’s updated warning and evacuation plans; and based on this assessment revised warning times in SQRA models from zero to 24 hours based on a highly regulated system with Keystone Dam releases on the Arkansas River. These updates decreased life safety risk associated with the levee system, and lowered the assigned risk category to a High risk rating for Levees A and B and Low risk rating for Levee C. More details about the 2019 SQRA can be found in the SQRA Summary Appendix D.

1.7 Tolerable Risk Guidelines and Life Safety

Per draft Engineering Circular (EC) 1165-2-218 (Levee Safety Program – Policy and Procedures), study teams used USACE Tolerable Risk Guidelines (TRGs) for levee systems throughout the study including problem identification and study objectives, conceiving solutions to identified problems to achieve study objectives, evaluating alternatives, and finally supporting decisions about risk management.

Per Planning Bulletin (PB) 2019-04 (Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies dated June 2019), one goal of planning studies that include an existing dam or existing levee system is to achieve all four TRGs through the formulation, recommendation, and implementation of cost effective plans that reduce the risk posed by the infrastructure. The TWT Project Delivery Team (PDT) has included specific objectives regarding TRGs.

Like all planning objectives, the extent to which TRG objectives can be met varies based on conditions in the study area and the efficiency and effectiveness of measures that contribute to achieving objectives. At a minimum, one alternative that addresses TRG 1 and TRG 4 must be identified. TRGs 1 through 4 are described in detail below.

TRG 1 - The first tolerable risk guideline involves determining whether society is willing to live with risks associated with the levee system to secure the benefits of living and working in the leveed area. USACE considered life safety, economic and environmental risk for TRG 1.

Life safety risk is considered in relation to two tolerable risk guidelines: societal life risk and individual life risk. The societal life safety tolerable risk line shown in Figure 1-6: Life Risk Matrix shows that society becomes more risk averse as life loss increases. Risks that plot above the societal life risk line are unacceptable except in extreme circumstances. USACE has chosen to use a 1 in 10,000 (i.e., 0.01 percent) per year frequency as the probability of life loss for an individual or group of individuals most at risk as TRG 1.

The primary focus during formulation of measures and alternatives because it establishes a threshold for life safety risk tolerability. The study team applied this standard only to the risks associated with under and through seepage (prior to overtopping risk). After life safety risk, economic and environmental risks were assessed to determine how they influenced meeting TRG1 for risks prior to overtopping.

TRG 2 - The second tolerable risk guideline involves determining that there is a continuing recognition of levee risk, because risks associated with levee systems are not broadly acceptable and cannot be ignored. The rationale for meeting TRG 2 was qualitatively considered:

- If the levee sponsor has access to and is aware of the best available levee risk information,
- If the community in the leveed area has been provided the best available risk information associated with the levee system; and,
- If flood risk (residual risk) and potential changes to flood risk over time have been communicated to the community.

TRG 3 - The third tolerable risk guideline involves determining that risks associated with the levee system are being properly monitored and managed by those responsible for managing the risk. The rationale for meeting TRG 3 will be determined qualitatively and may be met through demonstrated monitoring and risk management activities including: 1) an active operation and maintenance program, 2) visual monitoring (documented regular inspections), 3) updated and tested emergency plan, instrumentation program, and 4) a best available risk characterization.

TRG 4 - The fourth tolerable risk guideline involves determining that those responsible for managing risks associated with a levee system continue to reduce risks as much as possible.

The rationale for meeting TRG 4 will be determined qualitatively and USACE will take into account:

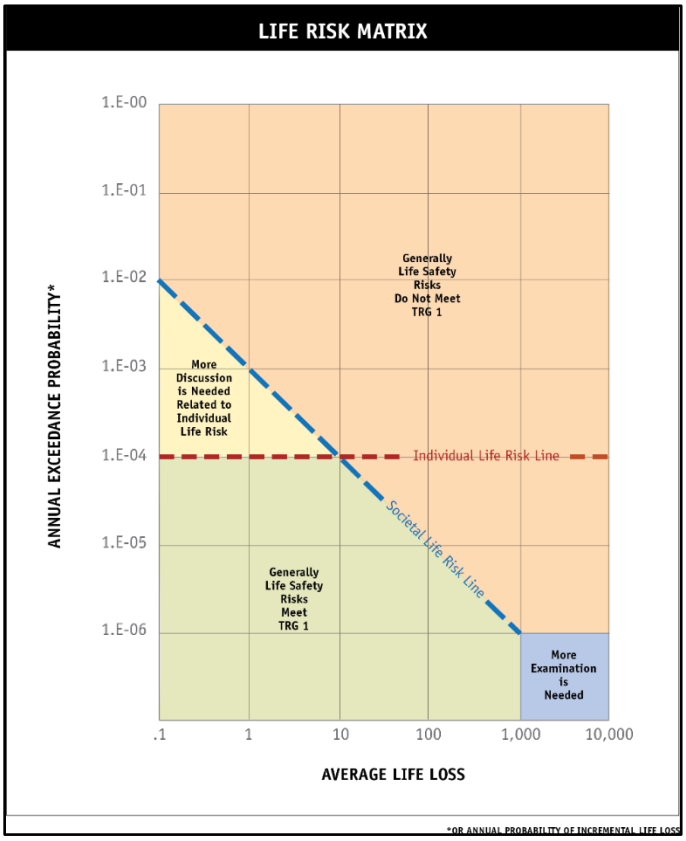

Figure 1-6: Life Risk Matrix

- The level of life safety risk in relation to the societal and individual tolerable risk guidelines,
- The disproportion between implementing the risk reduction measures and the subsequent risk reduction achieved,
- The cost-effectiveness of the risk reduction measures, and
- The societal concerns as revealed by consultation with the community and other stakeholders.

As noted above, plan formulation and evaluation during the study focused on achieving risks that society is willing to live with to secure certain benefits (TRG 1). TRG 2 through 4 primarily will be met through life-cycle OMRR&R requirements and a required floodplain management plan. Activities of the levee safety program may be identified and used to determine if and how TRG 2 through 4 are met. All requirements must be identified and accounted for in the benefits and costs in order for alternative plans to be considered effective and complete.

1.8 Reconstruction - USACE Policy Guidance

Per USACE Policy, the term “reconstruction” applies to the measures to address long-term degradation of project features, which have exceeded their expected service life. Reconstruction addresses impediments that prevent a project from performing as authorized after all maintenance, as required by the project operation and maintenance manual and the Code of Federal Regulations, has been accomplished and any deficiencies resulting from a lack of maintenance have been addressed. Reconstruction will consist of addressing major performance deficiencies caused by a long-term degradation of the foundation, construction materials, and engineering systems that have exceeded their expected service lives and the resulting inability of the project to perform its authorized project functions. In addressing reconstruction needs, the latest design standards and efficiency improvements should be incorporated into the project.

Reconstruction evaluation would be limited to individual project features (closure structures, pumping stations, gravity drains, relief wells, etc.). Features considered for reconstruction should determine whether there are any design or construction deficiencies or insufficient maintenance of the existing project.

A major reconstruction project with the Levee District under the existing USACE cost share requirements would permit the entire system to be evaluated and entail a full disclosure of future OMRR&R requirements for all components of the levee system. This comprehensive action, under current standards, would allow the entire system to become the responsibility of the non-Federal sponsor following completion and turn-over of the reconstructed system. This would allow receipt from the non-Federal sponsor of the assurances required to qualify under current criteria as a non-Federal sponsor, eliminating any future confusion regarding requirements for OMRR&R.

This study will evaluate the efficiency and effectiveness of the levee system and recommend a comprehensive plan to address long-term degradation of materials systems and components of existing project that have exceeded their expected service life within the TWT levee system.

CHAPTER 2: EXISTING AND FUTURE WITHOUT PROJECT CONDITIONS

The affected environment or existing condition is a baseline from which all of the future conditions are built, and is made up of the natural and physical environment, as well as, the relationship of people with the environment. The future without project condition, also known as the No Action Alternative (NAA), is the anticipated future for a given resource if no Federal action is implemented. The NAA serves as the baseline against which all action alternatives effects are measured.

The period of analysis for projecting the future without project condition is 50 years, which is the standard in most USACE planning studies and aligns with Engineer Regulation (ER) 1105-2-100. The 50-year period begins in 2024 and engineering and design prior to construction.

Chapter 2 describes existing and future without project conditions, and establishes a baseline for each of the following resources:

- Air quality
- Climate change and greenhouse gases
- Water resources (surface water, ground water, & water quality)
- Hydrology and floodplains
- Levees
- Aquatic resources (wetlands, open water habitats, & riverine sandbars)
- Natural resources (vegetation, fisheries & wildlife resources, & invasive species)
- Threatened and endangered species
- Cultural resources
- Land use, recreation and transportation
- Socioeconomics (demographics, environmental justice, & visual aesthetics)
- Utilities
- Health and safety
- Hazardous toxic and radioactive waste (HTRW)
- Topography, geology, and soils

In addition, it summarizes the affected environment as it relates to the National Environmental Policy Act (NEPA) that defines the affected environment as the natural and physical environment as well as the relationship of people to the environment.

2.1 Tulsa and West-Tulsa Levees

By the 1930s, the City of Tulsa was rapidly expanding west, and what had once been pasture and farmland was quickly morphing to industrial and residential property. This was especially true along the Arkansas River in Tulsa where by the 1940s, refineries, steel production facilities, chemical plants and heavy equipment manufacturers were helping the U.S. prepare for World War II. Given the area's strategic importance in the 1940s, USACE built the TWT levee system to protect industries and homes in the area from frequent flooding.

TWT levee system segments all have tiebacks along tributaries (Figure 2-1). The mainstem levee segments protect residential, commercial, and industrial areas from flooding along the Arkansas River, which flows from west to east, approximately 15 miles into Tulsa County, and then flows southeast through the county for about 25 miles. It has a drainage area of around 74,500 square miles above Keystone Dam, of which almost 23,000 square miles contribute to flood flows.

Keystone and Kaw Dams regulate flows in the Arkansas River in Tulsa County. There are other flood-control dams in the watershed, but these have minimal impact on the levee system. The minimum level of protection along the mainstem levee segments is roughly 360,000 cubic feet per second (cfs), which is approximately a 0.5 percent annual chance of exceedance (ACE) event. Overtopping would initially occur in the eastern portion of Levee B.

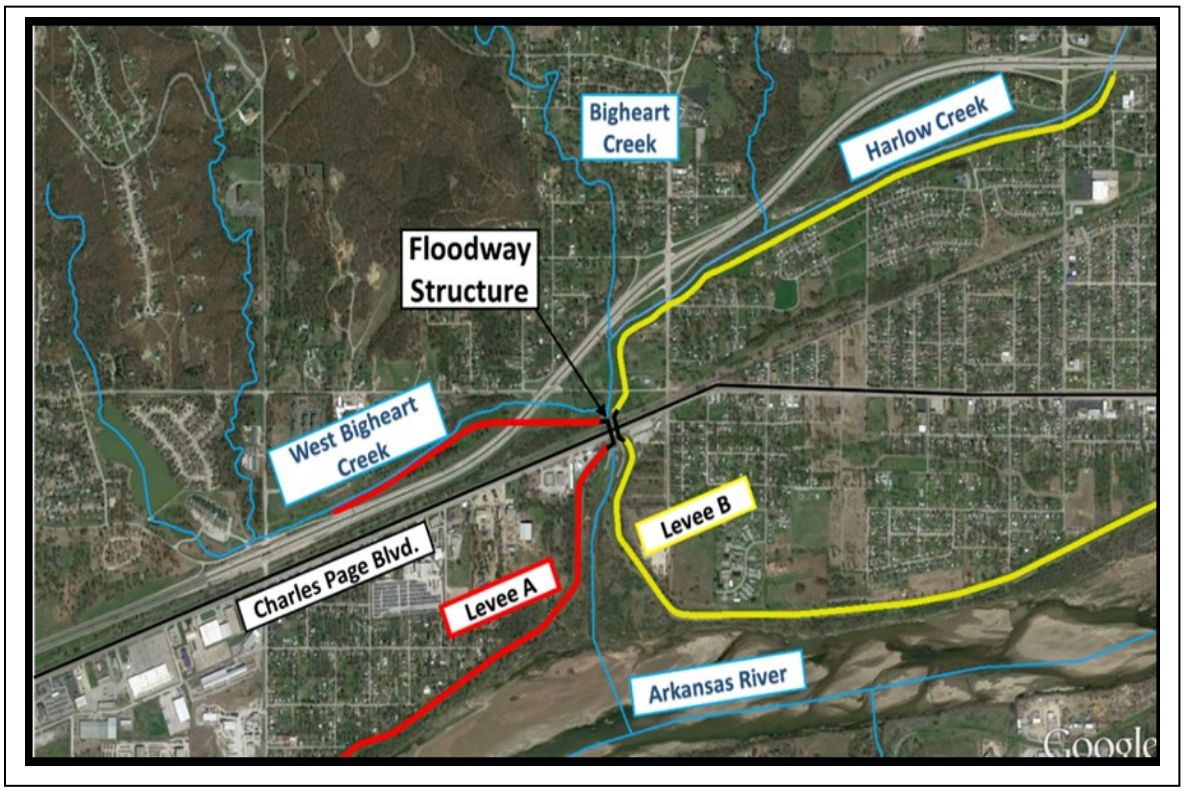

Figure 2-1: Map of Tributaries

Left bank tributaries that drain areas above Levees A and B consist of Bigheart, Harlow, and Parkview Creeks. Lower reaches of these streams have gentle slopes within the flat Arkansas River floodplain. West Bigheart Creek, a tributary of Bigheart Creek, is separated from the protected area by the Levee A tieback and is largely regulated by Sand Springs Lake. Harlow Creek separates from the protected area by the Levee B tieback. Bigheart Creek and Harlow Creek originate in Osage County, and the confluence of both streams occurs just upstream of the Charles Page Floodway Structure. Parkview Creek drains from the interior of Levee B and exits to the Arkansas River near Newblock Park.

None of the tieback levees along the tributaries protect adjacent areas to the 1 percent annual chance exceedance (ACE) flood, and significant interior ponding can occur during intense local storms. There are seven pump stations and interior ponding areas to address these issues (stations 1 through 3 are behind Levee A; stations 4 and 5 are behind Levee B; and stations 6 and 7 are behind Levee C).

Several floods have occurred along the Arkansas River in Tulsa County. Before construction of Keystone Dam, the flood of record occurred in October 1959, with an estimated peak flow of 246,000 cubic feet per second (cfs). The second largest pre-regulation flood was 244,000 cfs in June 1923. Since construction of Keystone Dam, significant flood-control releases occurred in 1974, 1986, 1993, 1998, 2007, and 2019. The two most significant releases occurred in October 1986, with a peak flow of 307,000 cfs; and May 2019, with a peak flow of 277,000 cfs.

Large floods on the tributaries, including Bigheart, Harlow, and Parkview Creeks, occurred in June 1974 and May 1984. There are no stream gages in the watershed; however, the June 1974 flood was estimated to have a 2 percent ACE based on high water marks. The 1984 Memorial Day Flood was the worst flood event in Tulsa's history. It affected most of the Tulsa metropolitan area, and was estimated to have a 1 percent ACE. Harlow Creek overtopped the Levee B tieback, affecting residential areas; most of the flooding resulted from rainfall occurring over the interior area.

2.1.1 Tulsa County Drainage District No. 12 (Levee District)

Drainage District No. 12, Tulsa County, Oklahoma (Levee District) accepted the completed project for operation and maintenance on August 7, 1945. In the following years, the Levee District has implemented operation and maintenance (O&M) of the levee utilizing the available funds and personnel. Also, there have been approved modifications to the project, including rehabilitating areas that were damaged by high water events. The following is an abbreviated list of modifications and rehabilitation for TWT Levees A and B.

- 1959, Levee B: Bank Stabilization with riprap protection was implemented from levee Stations 168+00B to 202+00B.
- 1960, Levee A: Steel Jetties added to the bank of the Arkansas River from approximate levee Stations 130+00A to 142+00A.

- 1984, Levee A: Repairs made to approximately 200 feet of Levee A embankment, and steel gas line was removed. Repairs were also made to the floodway structure, tieback levees, and outlet channel
- 1984 Levee B: Repairs made to approximately 1,100 feet of Levee B embankment at the overtopped section. A 54-inch CMP and headwall located just downstream of the floodway structure was also replaced.
- 1986, Levee A: Repairs were made to breach in Levee A embankment near Pump Station No. 1 and two drainage structures were replaced.
- 1989 Levee B: Mayfair Pump Station was built along Levee B Tieback by the City of Tulsa at Station 31+50B.
- 1990 Levee B: Drainage Improvements and Pump Station No. 5 Modifications.
- 1990: Levee A: Various broken collector drain caps were replaced.
- 1993-2002 Levee A&B: Plugging, removal, or replacement of various original drainage culverts.
- 1997 Levee B: Vern and Rayburn Pump Station constructed by the City of Tulsa at Station 177+00B.

The Levee District has had many different personnel assist in the implemented of the O&M plan to address issues as they arise, while also maintained the flood components that were in their capability, including the frequent testing of pump house equipment. During this time, USACE has performed routine and periodic inspections to assess the condition of the levee and the execution of the O&M by the drainage district. The Levee District is still responsible for O&M detailed in an updated O&M Manual from 2002. As discussed in Chapter 1, many aging levee systems do not include RR&R requirements in O&M Manuals. However in 2005, the Levee Safety inspection program began performing more in-depth and more frequent inspections of the levee system.

In December 2007, USACE Tulsa District, gave the TWT levee system an Unacceptable rating, due to the tree growth on the levee and plugged and damaged drainage relief wells and toe drain manholes. The Unacceptable rating has carried over into the subsequent inspection due to these same issues. As a result of receiving an Unacceptable rating, the drainage district was kicked out of the PL84-99 rehabilitation program. On 6 June 2012, the Drainage District had a Letter of Intent (LOI) approved granting the TWT levees admittance to the System Wide Improvement Framework (SWIF) plan. The Levee District's SWIF plan detailed their plan to address deficiencies; identified funding sources and resources; and the timeframe the deficiencies are to be addressed. During the SWIF, the levee sponsor has been able to meet their outlined goals and has secured funding sources to facilitate the rehabilitation of the levee components. The SWIF plan is being updated as part of the Levee District's continued efforts to improve the condition of the levee and appurtenant structures. Items that have been addressed during the SWIF plan from 2016 to 2018 and future action items for 2019 and 2020 are listed below.

SWIF Action Plan - Completed Items (2016 to 2018):

1. Airborne topographic LiDAR of the 20 miles of protection area.
2. Geotechnical assessment determine extent of under seepage.
3. Provide design to correct/control under seepage issues.
4. Compete Geotechnical exploration including boring along the crest.
5. Geotechnical analysis.
6. Design solution with cost estimate of geotechnical findings.
7. Design of toe drain system.
8. Complete video and pipe structure assessment.
9. Complete buoyancy calculation of floodway conduit.
10. Survey and annotate all existing encroachments.
11. Complete and document a comprehensive survey of all known penetrations.
12. Monthly Team IPR.

SWIF Action Plan – Future Items (2019 to 2020):

1. Use LiDAR to develop map of flood extent areas for community education, evacuation, and response planning.
2. Complete drainage repair or replacement.
3. Complete under seepage repair as outlined in design.
4. Integrate geo technical analysis for completion of construction projects.
5. Implement design solutions found within the Geo Technical Report.
6. Complete construction of toe drain repairs that support relevant drainage shortfalls.
7. Utilize video during construction phase.
8. Complete and exercise response plan for floodwall floating during events.
9. Utilize encroachments for construction.
10. Complete project to approve or disapprove all identified penetrations.

In 2015, a high water event caused washout of a culvert outlet discharge area. With the assistance of USACE, this area was being repaired though a Post Incident Report (PIR) as part of the PL84-99 Rehabilitation Program. However, during the May 2019 Flood Event on the Arkansas River in Tulsa, Oklahoma, the levee experienced its second largest loading and longest duration flood event. The damage sustained during this flood event consisted of erosion at the same location in the 2015 high water event, seepage and backwards erosion piping at the floodwall structure on Charles Page Blvd, damage/failure of the pumps at the pump stations, including additional items. USACE is addressing these issues; the levee sponsor continues to operate and maintain the drainage district to ensure correct performance of the levees.

2.1.2 May 2019 Flood Event

During the May 2019 flood event, peak releases out of Keystone Dam were 277,000 cfs. At 100,000 cfs flows, emergency response resources were activated. When flows reached 150,000 cfs, Levee District personnel and engineers inspected and monitored the levee for signs of distress or issues. At 200,000 cfs, residents were advised to evacuate. The City of Tulsa used sirens, door-to-door notification, local media, social media, and loud speakers to warn the population at risk. The refinery behind Levee C temporarily shut down when flows in the Arkansas River were forecast to reach 250,000 cfs, although levees A, B and C were not fully loaded. The flood of 1986 had peak releases out of Keystone Dam totaling 305,000 cfs for 12 hours. The 2019 flood event had peak releases of 277,000 cfs for 30 hours and over 200,000 cfs for 10 days. Plan formulation for this study relied on hydrologic data from the above events as benchmarks.

2.1.3 Semi-Quantitative Risk Assessment (SQRA) 2016-2017

The 2016 – 2017 TWT SQRA assigned a risk category of “Very High” to levees A and B and a risk category of “High” to Levee C. Risk characterizations are based on two factors, likelihood of levee failure and resulting life loss. The SQRA team concluded that the likelihood of levee failure from overtopping and internal erosion was Very High and also characterized life loss estimates from a breach as Very High. More details about the SQRA can be found the SQRA Summary Appendix D.

2.1.4 SQRA 2019 Performed in this Study

The Southwestern Division Cadre, Risk Management Center (RMC), Southwest Tulsa District (SWT), and local levee district representatives met during March 2019 to update the SQRA. The 2019 SQRA assessed Tulsa County’s updated warning and evacuation plans; and based on this assessment revised warning times in SQRA models from zero to 24 hours based on a highly regulated system with Keystone Dam releases on the Arkansas River. These updates decreased life safety risk associated with the levee system. More details about the 2019 SQRA can be found in the SQRA Summary Appendix D.

2.2 Existing Conditions and Future without Project Conditions

Conditions described in this section summarize the technical evaluations of the National Environmental Policy Act (NEPA) and other resources that drive the reduction of life and flood damages risk. Although, not the deciding criteria, the PDT will calculate and discuss the National Economic Development (NED), as appropriate. When not discussed separately it is assumed the existing conditions for a resource for each area is similar. While all NEPA resources are significant to various institutions, this section discusses only those resources that would be directly or indirectly impacted by the proposed alternatives. Details on both the existing condition and NAA are detailed in the following sections. Figure 2-2 shows the existing TWT Levees System and overall study area.

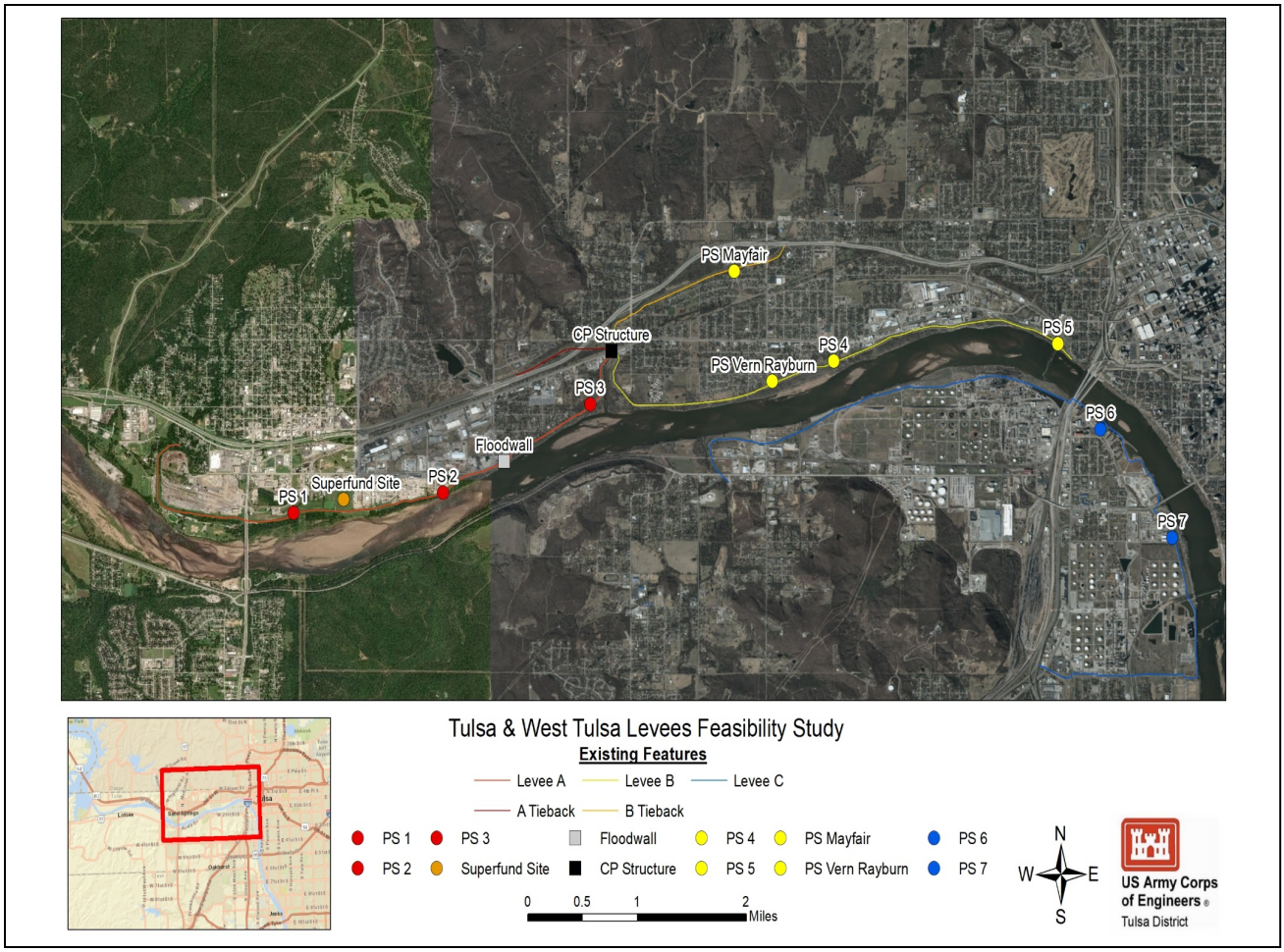

Figure 2-2: Existing Levee and Flood protection Structures in the Project Area

2.2.1 Air Quality

Ground-level ozone is the main criteria pollutant of concern for the Tulsa metropolitan area. Motor vehicle exhaust and industrial emissions, among other sources, emit nitrogen oxides and other volatile organic compounds, which react with sunlight to form ground-level ozone. Ozone accumulation is at its highest during warm weather months.

The U.S. Environmental Protection Agency (EPA) has the primary responsibility for regulating air quality nationwide. The Clean Air Act (42 U.S.C. 7401 *et seq*.), as amended, requires the EPA to set National Ambient Air Quality Standards (NAAQS) for wide-spread pollutants from numerous and diverse sources considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards classified as either “primary” or “secondary.” Primary standards set limits to protect public health, including the health of at-risk populations such as people with pre-existing heart or lung diseases (such as asthma), children, and older adults. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.

EPA has set NAAQS for six principal pollutants, which are called “criteria” pollutants. These criteria pollutants include carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter less than 10 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$), sulfur dioxide (SO_2) and lead (Pb). If the concentration of one or more criteria pollutant in a geographic area is found to exceed the regulated “threshold” level for one or more of the NAAQS, the area may be classified as a non-attainment area. Areas with concentrations of criteria pollutants that are below the levels established by the NAAQS are considered either attainment or unclassifiable areas.

The Tulsa area was designated an attainment area for ozone in 1990 after 20 years of nonattainment designation. As of the time of this publication, the Tulsa area and the State of Oklahoma remain in attainment.

FWOP: This resource is not expected to change significantly during the planning horizon of this project compared to the existing conditions. While ongoing construction associated with various projects is expected to continue in the Tulsa area, local, state, and federal emission standards are expected to maintain air quality attainment standards in the Tulsa area.

2.2.2 Climate

The climate in the Tulsa area is considered continental, characterized by abundant sunshine and rapid fluctuations in temperature. Winters are generally mild, and temperatures rarely fall below 0 degrees Fahrenheit (°F). During the summer, temperatures often exceed 100°F from late July to early September. The average annual temperature is 61°F, with average highs ranging from 79°F to 93°F during summer and from 38°F to 50°F during winter. Average low temperatures in the winter months generally range between 28°F and 40°F (NWS, 2018).

Average annual precipitation in the study area is 41 inches (NWS, 2018). Thunderstorms account for a significant amount of the annual precipitation and are most frequent in the spring. Generally, wet weather events take place only for a day or two, followed by fair skies. Snowfall is most prevalent in January and early March, with annual snowfall amounts averaging 9.6 inches (NWS, 2018). In addition to local precipitation, rain and snowfall events throughout the Keystone Lake watershed can impact flow conditions in the Tulsa area.

Large hail and windstorms may occur throughout the year, but are most common in spring and early summer. Typically, these storms create scattered damage. Oklahoma has a very high level of tornado activity, with an average of 56 tornadoes a year state-wide (NWS 2017A), with an average of 2 tornadoes occurring in Tulsa County per year (NWS, 2017B).

FWOP: Over the planning horizon (50 years), local weather events, like flooding and droughts, may become more frequent and intense with the influence of climate change. Additional details are given in the section below.

2.2.3 Predicted Climate Change

The U.S. Global Change Research Program (USGCRP) looks at potential impacts of climate change globally, nationally, regionally, and by resource (e.g., water resources, ecosystems, human health). The TWT study area lies within the Southern Great Plains region of analysis. The Southern Great Plains region has already seen evidence of climate change in the form of rising temperatures that are leading to increased demand for water and energy and impacts on agricultural practices. Over the last few decades, the Southern Great Plains have seen fewer cold days and more hot days, as well as an overall increase in total precipitation. The decrease in the cold days has resulted in an overall increase of the frost-free season. Within this region, there has been an increase in average temperatures 1.2° Fahrenheit (F) for the period 1986-2016 (USGCRP 2018). In addition to more extreme rainfall, extreme heat events have also been increasing. Most of the increases of heat wave severity in the U.S. are likely due to human activity, with a detectable human influence in recent heat waves in the Southern Great Plains (USGCRP, 2018).

This trend of rising temperatures and more frequent extreme events such as heat waves, drought, and heavy rainfall is predicted to continue into the future (USGCRP 2018). The USGCRP looks at two potential future conditions as part of its predictive modeling process. Under conditions of lower greenhouse gas (GHG) emissions, the average temperature in the Southern Great Plains region may increase as much as 5.1°F by 2050, and 8.4°F by 2100 from averages observed from 1976–2000. If the current rate of GHG emissions continues, the potential increase is greater in the long-term, which may result in as much as 60 days with temperatures over 100°F by 2100.

FWOP: Climate is predicted to become warmer, and potentially wetter within the study area without widespread measures to curb GHG emissions and reverse the impacts of predicated climate change. Droughts and rain events are also anticipated to be more intense in the future.

2.2.4 Water Resources (Surface water, Ground water)

Section 2.2.4 characterizes the surface water and groundwater resources of the study area as well as the quality of these waters.

Surface Water

The Arkansas River drains approximately 75,700 square miles (mi^2) upstream of Tulsa, of which nearly 50,000 mi^2 contribute to flows through Tulsa. The river corridor is characterized by a wide channel with large meanders, point bars, and braided channels through most of the study area, except for the pool behind Zink Dam. The active channel is wide and flat-bottomed with a representative channel width of 1,500 feet and a representative depth of 20 feet (USACE, 2011).

Using the United States Geological Survey (USGS) StreamStats topographic map viewer at a scale of 1:36,111, a total of 35 tributaries, 18 named and 17 unnamed, were identified within the TWT project area (USGS, 2018). Tributaries are not only important hydrologic features, but they are ecologically significant due to the habitat diversity they provide. The named tributaries are perennial streams, whereas the unnamed tributaries are typically intermittent. The total number of tributaries equates to an average of one tributary every 1.2 miles along the study area.

Zink Lake is an impoundment pool on the Arkansas River formed as a result of the construction of the John Zink Dam, a low-water dam built in 1984. Zink Lake extends from 29th Street at the dam location, upstream to the Southwest Boulevard Bridge. The pool created by Zink Dam is relatively short, a little over 2 miles in length, and is broken into two pools by a shoal area about 1.2 miles upstream of Zink Dam. Construction of the dam substantially affected the deposition of sediment in the streambed, resulting in greater deposits of sand and gravel within the area. The Arkansas River channel at Zink Lake is approximately 1,500 feet wide at bank full stage. The River Parks Authority, an organization created by the City of Tulsa and Tulsa County, is currently authorized and permitted to excavate and relocate sands within the Arkansas River channel as part of the Zink Lake and Zink Dam maintenance program for the reoccurring sediment accumulation in Zink Lake.

Groundwater

The September to October 2014 baseline sampling included 29 groundwater quality sites and 22 water level sites. Maximum contaminant levels (MCLs), set by the EPA under the Safe Drinking Water Act, to include: primary MCLs to address health concerns and secondary MCL's to address concerns like taste and odor. The Groundwater Monitoring and Assessment Program (GMAP) for the study area found some elevated MCLs for Total Dissolved Solids (mg/L), dissolved Iron (µg/L), and dissolved Manganese (µg/L) (OWRB, 2015).

The alluvial aquifer along the Arkansas River in the study area ranges in thickness from 20 to 40 feet. The alluvium consists of relatively permeable coarse sand and fine gravel overlying bedrock, which is in turn overlain by floodplain deposits of silt and fine sand (Marcher and Bingham, 1971). Bedrock is composed of low-permeability shale. It is reasonable to assume there is little groundwater transfer between the shallow alluvial aquifer and deep regional aquifers in the study area (CH2M Hill, 2010). Based on depth-to-water data from some well completion reports in the area, the water table generally ranges from about 8 to 29 feet below grade. Of the 154 wells in the study area, 57 were identified as supply wells for commercial, domestic, industrial, irrigation, or public use. One of the wells was listed as a domestic well for a Sand Springs public school. The remaining wells were either dewatering/corrosion protection wells or monitoring wells/extraction wells, presumably installed for previous or ongoing water quality investigations in the area. Within the reach between Keystone Dam and Highway 97, 20 wells were identified: 13 domestic, five irrigation, one used for soil evaluation, and one "other" (either commercial, corrosion protection, dewatering, industrial, observation well, public water supply, pump and treat, or water location).

FWOP: Surface and ground water resources of the area are not expected to change significantly in the future without project condition. The majority of the lands protected by levees have already been developed. Federal, state, and local laws and regulations are in place to limit, prevent, and account for impacts to these resources.

2.2.5 Water Quality

Beneficial uses are designated for each of the state's water bodies as a requirement of the Clean Water Act (CWA). For each waterbody, designated beneficial uses have water quality criteria defined in the state's water quality standards (WQS) (Title 785 OAC). These criteria are designed to maintain a waterbody at a level necessary to meet its designated uses (OWRB, 2016A). Designated beneficial uses of the Arkansas River below Keystone Dam are the following (USACE, 2018):

- Emergency water supply,
- Fish and wildlife propagation – warm-water aquatic community,
- Agriculture,
- Secondary body contact recreation,
- Navigation; and,
- Aesthetics.

If a waterbody does not meet the requirements as set forth in the state's WQS, it is "impaired" and is listed as such on the CWA 303(d) List of Impaired Waters (OWRB, 2016B). The CWA requires that each state report its water quality on a biennial cycle. EPA Region 6 has approved Oklahoma's 2016 303(d) list of impaired waters.

Table 2-1: Summary of 303(d) Lists for the Arkansas River within the Study Area (2015 through 2016) provides a summary of the water bodies found within 303(d) list.

The Indian Nations Council of Governments (INCOG) is the designated Water Quality Management Planning Agency for the Tulsa region. INCOG monitored summer flows and temperatures at eight sampling sites during extreme critical conditions in 2011, in the midst of the worst drought in Oklahoma's recorded history (INCOG, 2012). Monitoring sites spanned the river reach from Highway 97 at Sand Springs to Hwy 67 in Bixby. Releases from Keystone Dam were minimal to no flow for many days on end (INCOG, 2012). The diurnal sampling study revealed that even under the extreme and unprecedented critical conditions during August 2011, the minimum dissolved oxygen (DO) concentrations at all eight sites measured at dawn were greater than the minimum DO WQS for summer of 5.0 milligrams per liter (mg/L). INCOG noted, "This is likely due to super-saturated water from the previous day's high DO concentrations of around 120 percent to 140 percent at most sites, along with the continuous flow of around 100 cfs of very shallow water frequently tumbling over bedrock and large rocks causing mechanical aeration from the air."

Table 2-1: Summary of 303(d) Lists for the Arkansas River within the Study Area (2015 through 2016)

River Segment	Location	Impairment
OK120420010010_10	Berryhill Creek to Cherry Creek	Cadmium
OK120420010010_00	Cherry Creek to Snake Creek	Enterococcus and Turbidity
OK120410010080_00	Broken Arrow Creek to Muskogee Creek, North	Enterococcus
OK120420010130_00	Arkansas River from mouth of Verdigris River to Keystone Dam	Turbidity

Source: ODEQWQD, 2016

Low concentrations of carbonaceous biological oxygen demand and ammonia-nitrogen were measured during the summer 2011 diurnal study, indicating low levels of organic material from sewage and stagnant areas (INCOG, 2012). INCOG reported, “This is likely because all wastewater treatment plants within the project area are performing well, and even under the extreme summer conditions of 2011 there still was a residual base flow in the river of around 100 cfs that likely prevented stagnation of pools and the consequent collection of organic materials.” In the absence of typical scouring flows associated with generation, noticeable amounts of attached algae were observed at all eight sampling sites (INCOG, 2012).

INCOG (2012) concluded that while their studies indicate a river that is returning to full beneficial use attainment, there are continuing indications of water quality issues that need to be addressed in the future. These indicators were identified as bacteria, metals, and nutrients. INCOG also noted that the extent of future reductions in the bacteria loading would depend upon the effectiveness of bacteria reduction programs in the watershed. Finally, INCOG’s diurnal study indicated that, under prolonged periods of relatively low flows (mostly less than 1,000 cfs), there is an abundance of attached algae in the river which increases DO during daylight and utilizes DO after dark.

FWOP: Water quality of area water bodies is not expected to worsen in the FWOP condition. Various local, state and federal agencies continue to address water quality needs of the area, as such increase in water quality can be expected as pollution sources are addressed and wastewater treatment technology advances.

2.2.6 Hydrology and Floodplains

Historically, the Arkansas River was an uncontrolled prairie river, but anthropogenic influences over the past century have greatly affected the river. With completion of Keystone Dam in 1964, river dynamics below the dam changed.

According to USGS data, since the dam began operation, daily flows have averaged about 4,000 cfs at the Tulsa gage (located on the 11th Street Bridge near downtown Tulsa), and approximately 5,200 cfs at the Haskell gage (located on the State Highway 104 Bridge near Haskell, Oklahoma). Annual flows at both locations have averaged 8,400 and 10,100 cfs, respectively. Instantaneous annual peak flows near Haskell are typically about 3,000 cfs greater than those measured at the Tulsa gage; however, the magnitude of the difference has varied widely. For example, the peak flow rate at Haskell exceeded Tulsa by 29,000 cfs during the event of March 3, 1990. Conversely, during the event of October 5, 1986, the peak at Haskell was 48,000 cfs less than Tulsa.

The Federal Emergency Management Agency (FEMA) Flood Insurance Study for Tulsa County and incorporated areas lists several peak discharges associated with a probability of occurrence in any given year for the Arkansas River in the Tulsa area (FEMA, 2016):

- 10-percent (10-year event): 90,000 cfs,
- 2-percent (50-year event): 155,000 cfs,
- 1-percent (100-year event): 205,000 cfs; and,
- 0.2-percent (500-year event): 490,000 cfs.

The 10-year event (90,000 cfs) equals the maximum lake regulating discharge typical of Keystone Lake. The channel capacity downstream of Keystone is currently estimated at 105,000 cfs. Current releases from Keystone range from 0 to 105,000 cfs; however, releases may be modified to meet requirements of the Arkansas River system operating plan. When the Arkansas is below channel capacity, and releases from Keystone Dam are increasing, the maximum increase is 15,000 cfs, and the minimum time between changes is 2 hours. When the Arkansas River is below channel capacity, and releases from Keystone Dam are decreasing, the maximum decrease is 15,000 cfs, and the minimum time between changes is 3 hours.

Monthly mean flows in the Arkansas River are typically highest during the spring and summer. From March through July, long-term average monthly mean flows exceed 10,000 cfs at both Tulsa and Haskell, and from August through February, long-term average monthly mean flows are less than 8,000 cfs. The smallest difference in a given month between long-term maximum and minimum monthly mean flows occurred in December and was nearly 17,000 cfs. Conversely, the largest happened in May and exceeded 80,000 cfs. Monthly mean flows at Arkansas City, Kansas are slightly higher during the spring and summer; however, the relative magnitude of differences in flow between seasons is much less dramatic than observed at Tulsa and Haskell.

A significant characteristic of river hydraulics in the study area are high-frequency, large amplitude flow fluctuations resulting from the operation of Keystone Dam. Flows in the area regularly fluctuate up to nearly two orders of magnitude within time intervals as short as 24 hours. Another significant effect of Keystone on the Arkansas River has been a reduction in downstream sedimentation. The mean annual suspended sediment concentration decreased by

82 percent from 1,970 mg/L (1931 through1964) to 350 mg/L (1965 through 1995) at the Tulsa gage. Similarly, average annual suspended sediment flux fell by 73 percent from 14.7 to 4.0 mega-tonnes after completion of the dam. The Haskell gage station exhibited a similar post-dam pattern of annual fluxes; however, with the Haskell station has always had a greater annual flux than the Tulsa station.

Floodplains are normally dry land areas adjoining surface waters that inundate during floods. The 100-year floodplain includes areas subject to a 1 percent chance of flooding in any given year, and the 500-year floodplain is subject to a 0.2 percent chance of flooding in any given year. Areas in a designated floodplain may be subject to more frequent flooding than the assigned risk would indicate. FEMA Flood Insurance Rate Maps were reviewed to assess relationships between the study area and FEMA-designated floodplains. Most regions in the study area are designated as either “AE” (high risk areas) or “X” (moderate to low risk areas) (FEMA, 2011). Floodplains along the Arkansas River and its tributaries between the conservation pool and top of the flood control surcharge pool (756.0 feet msl) may become inundated at various frequencies.

Multiple streams were realigned and modified during the construction of the TWT system. These include Harlow Creek, Bigheart Creek, Lake Station Drainage Ditch (hereafter referred to as Bigheart Creek Tributary), and Cherry Creek. The three tributary streams on the north side of the Arkansas River (Harlow Creek, Bigheart Creek, and Bigheart Tributary) used to arrive at different confluence locations. However, it became advantageous to combine these three drainage areas into a single outlet on the north side of the Arkansas River. This new confluence was designed to be controlled by the Charles Page Boulevard Floodway Structure which would also allow for the closure and linkage of Levees A and B along with their respective tieback segments.

Bigheart, Harlow, and Parkview Creeks are left bank tributaries of the Arkansas River that drain areas above Levees A and B. The lower reaches of these streams have gentle slopes within the flat Arkansas River floodplain. West Bigheart Creek, a tributary of Bigheart Creek, is separated from the protected area by the Levee A tieback and is largely regulated by Sand Springs Lake. Harlow Creek is separated from the protected area by the Levee B tieback. Bigheart Creek and Harlow Creek both originate in Osage County, and the confluence of both of these streams occurs just upstream from the Charles Page Floodway Structure.

Harlow Creek flows for a total of approximately 3.5 miles. Originally flowing south, stream slopes in the headwater areas approach 25 ft/mi. After passing beneath the US-412 Highway embankment, Harlow Creek flows in a southwesterly direction along the Levee B Tieback embankment with an average slope of approximately 7.5 ft/mi. The largest tributary to Harlow Creek (termed “Harlow Creek Tributary”) enters from the north and contributes approximately 2.25 sq. mi. to the seven sq. mi. total drainage area. Starting at West Edison Street, Harlow Creek has been realigned and channelized for its remaining length to the confluence with Bigheart Creek.

FWOP: The hydrology of the study area is not expected to change in the FWOP as river flow through the study area is largely controlled by Keystone Dam. Floodplains, however, may be reevaluated based on recent flooding events.

2.2.7 Levees

Between 1938 and 1945, USACE constructed five levee systems along the Arkansas River and tributary creeks in Tulsa County (TWT Levee systems). Beginning in 1945, the levees were transferred to the Levee District of Tulsa County, which assumed responsibility for long-term OMRR&R. The three disconnected levees are known as levees “A,” “B,” and “C” with levees A and B running along the left bank and Levee C along the right bank as shown in Figure 2-2 at the beginning of Part 2.

Levees A and B both converge at a floodway structure known as the Charles Page Floodway Structure. In their current state, the levees are prone to erosion, seepage, and lifting occurring at the Charles Page Floodway Structure. The 3 levees protect over 10,000 people and over 3,000 structures and property worth $1.79 billion. There are 3 federally built and owned pump stations along Levee A, 2 along Levee B, and 2 along Levee C. There are also 2 pump stations that are locally owned, one on the west side of Levee B and one on the Tieback side of Levee B. Levee A intersects the Sand Springs Petrochemical Complex Superfund site between pumping stations 1 and 2; this Superfund site historically had concerns of contaminated soils and groundwater resulting from industrial land use, but is no longer on the National Priorities List as of 2000.

Appendices A, B, and D describe the current function of the levee system regarding flood protection. During the 2019 flood events, while the levees did not experience a severe loss of function, various sandbagging, supplemental pumping, and evacuation efforts were needed to ensure no loss of life occurred.

FWOP: In the FWOP, the TWT levee system would continue to degrade without substantial increases in maintenance, rehabilitation, and rebuilding efforts. As such, flood risk to life and property in the protected areas of the levee could increase over time, especially during large flood events, without substantial levee system upgrades.

2.2.8 Aquatic Resources

Aquatic resources in the study area include wetlands, intermittently and permanently inundated open water and riverine habitats, and riverine sandbars.

Wetlands

At lower river elevations, wetlands consist of emergent herbaceous wetlands and riparian shrub wetlands characterized by rooted, herbaceous hydrophytes that typically grow in flooded soils. Emergent wetlands can be found along the edge of the Arkansas River and in depressional areas on the riverside of the TWT. Almost no wetlands occur within the landside of the levees.

Emergent wetlands provide food and shelter for fish and a number of other species, including macroinvertebrates, which make up the foundation of the aquatic food chain, and habitat for various amphibians, reptiles, birds, and insects. Frogs and salamanders use emergent wetlands for breeding grounds and egg-laying. Ducks and migratory birds use them for resting areas on migration routes and for nesting. Abundant aquatic insects provide a food source for fish, aquatic invertebrates, amphibians, reptiles, and birds, and break down organic material present in riverine and riparian wetland areas. Since these wetland communities are found in lower elevations, or are associated with more permanent open water habitats, they have been the most susceptible to disruptive and unnatural flow regimes resulting from the construction and operation of Keystone Dam.

Riparian shrub wetlands are open, occasionally flooded areas dominated by shrub and hardwood saplings mixed with emergent herbaceous vegetation. Riparian shrub wetlands provide shelter, food, and nesting habitat for a variety of wildlife. These wetland communities are found at elevations slightly above emergent wetland communities and adjacent to river banks where less frequent inundation by flows and reduced scour allows shrub and sapling strata to establish.

The frequent and extreme river fluctuations from hydropower operations have a drying effect on wetland habitats that serve as nurseries for juvenile fish and habitat for migrating waterfowl, producing an overall reduction in the diversity of the species using these habitats. Periods of high flows followed by low flows further affect the geomorphology of the river producing increased streambank erosion and the destruction of riverine wetlands and oxbow habitats, further reducing the availability of productive habitats (USACE and TVA, 2009). Wetland habitats located within the active river channel are dominated by emergent herbaceous communities. These communities are more prone to structural instability from rapid changes in the flow regime making their size and placement in the river corridor more transient. Wetland soils and emergent vegetation are subject to habitat smothering from changes in river geomorphology. Frequent desiccation also reduces formation of wetland soils and selects for early successive invasive species such as Johnson grass (*Sorghum halepense*) that impact vegetation strata.

Almost no wetlands exist within the levee protected areas outside of manmade detention ponds for various industrial, commercial, and/or storm runoff storage.

Open Water Habitats

Open water habitats in the mainstem of the Arkansas River channel include riffle and pool run complexes, isolated pools, and reservoir pools (Zink Lake). Riffle and pool run complexes are typical of prairie river systems. They are braided and relatively nonpermanent features redeposited in the river channel during higher-flow conditions. Isolated pools of open water are less common throughout the study area. They include features created through natural processes such as oxbows, which are relics of meandering riffle and pool run complexes, and those created through anthropogenic activities such as sand mining and at locations below stormwater outfalls entering the river.

Many of these isolated pools are temporary as braided riffle and pool run complexes meander under various river flow conditions and as riverine sandbars shift and are redeposited. More persistent pools are found adjacent to the river channel banks and connect to other surface waters under higher river stages. Many have emergent and shrub wetland vegetation, creating a littoral fringe that helps to stabilize the substrate. Water quality in the more persistent pools is typically low due to stormwater inputs and little to no mixing with other surface waters. Substrates within these pools includes sand and organic sediments.

Open water habitats in the study area, mainly the Arkansas River and its tributaries, support a valuable recreational fishery to area residents. Additionally, populations of smaller fish that are forage species for shore birds and wading birds are relatively abundant in these habitats. Smaller forage fishes are most abundant in pool runs, Zink Lake, and temporary and permanent isolated pools in the river channel. Their local seasonal abundance depends on river flows, connections of pools to other river channel surface waters, and water quality.

Listed species that forage in the open water habitats include the interior least tern (*Sterna antillarum athalassos*). Piping plover (*Charadrius melodus)*, and red knot (*Calidris canutus rufus)* are also listed for the area but have been rarely, if ever, seen near the study area. Least tern forage along the sandbars and pools at the stream confluence with the Arkansas River. Their use of the stream habitat along tributaries, like Harlow Creek and Bigheart Creek, channel into the urbanized watershed is unlikely with the majority of resources occurring within the Arkansas River.

Riverine Sandbars

Riverine sandbars dominate river channel habitats during lower-flow conditions, and their size, location, and stability depend on controlled flow conditions through releases from the Keystone Dam. During typical river stage conditions (less than 12,000 cfs), sandbars in the area are dry, but during higher river stage conditions, they partially or fully submerge.

Riverine sandbar habitats in the area are mostly un-vegetated and subject to cycles of scour and deposition. At slightly higher elevations nearer river banks, sandbars are less frequently inundated and have more vegetation, which when established is typically herbaceous, shrubs,

or smaller trees such as black willow (*Salix nigra*), sandbar willow (*Salix interior*), buttonbush (*Cephalanthus occidentalis*), and sycamore (*Platanus occidentalis*). The invasive species Johnson grass is also abundant here. At their highest elevations, sandbar habitats include bank slopes of the Arkansas River. Most riverbanks are steep to near vertically sloped with areas that are sloughing and or eroding or are reinforced with riprap or concrete rubble.

The primary ecological functions that sandbars provide include floodwater attenuation during high river stage events; sources of sediments for downstream habitats; habitat for listed species; and foraging habitat for wading birds, waterfowl, and terrestrial species. In the study area, riverine sandbars have potential to provide habitat for the federally listed the interior least tern.

FWOP: Under the FWOP, the Arkansas River and associated wetlands, sandbars and open water habitat are expected to benefit from the construction of the recently completed Arkansas River Corridor Ecosystem Feasibility Study and the future increase of riverine habitat. Within the levee protected areas, few aquatic resources exist outside of manmade features. Overall, outside of the Arkansas River, little change is expected for aquatic resources in the study area.

2.2.9 Natural Resources

Vegetation

Three basic vegetation zones can be found in the project area: upland forest, bottomland hardwood, and urban.

The upland forest vegetation zone refers to the Post Oak-Blackjack types in the Central Great Plains ecoregion that represents a mixture of forest and grassland ecosystems characteristic of most of the shoreline and recreation areas. The overstory is composed largely of blackjack oak (*Quercus merilandica*), post oak (*Quercus stellata*), eastern red cedar (*Juniperus virginiana*), and black hickory (*Carya texana*). Various species of sumac, berries, and grasses make up the understory growth.

The bottomland hardwood vegetation zone has, for the most part, been inundated by the river. The principal tree species found on the river bottoms are northern red oak (*Quercus rubra*), black oak (*Quercus velatina*), chinquapin oak (*Quercus muehlenbergi*), overcup oak (*Quercus lyrata*), sycamore (*Platanus occidentalis*), cottonwood (*Populus deltoides*), black willow (*Salix nigra*), black walnut (*Juglans nigra*), pecan (*Carya illinoensis*), river birch (*Betula nigra*), winged elm (*Ulmus alata*), slippery elm (*Ulmus ruba*), hackberry (*Celtis laevigata*), sassafras (*Sassafras albidum*), hawthorn (*Crataegus sp.*), redbud (*Cercis canadensis*), honey locust (*Gleditsia triacanthus*), red maple (*Acer rubrum*), box elder (*Acer negundo*), dogwood (*Cornus florida*), white ash (*Fraxinus americana*), green ash (*Fraxinus pennsylvania*), swamp privet (*Forestiera acuminata*), and buttonbush (*Cephalanthus occidentalis*). The shallow upland soils support the growth and vitality of the native Blackjack forest vegetation. Both the upland forest and

bottomland hardwood vegetation zones within the TWT project area occurs in narrow strips of 100 ft. wide but can go on for miles.

The urban vegetation zone refers to the mowed, manicured, and planted areas with ornamental planted areas. This is the largest basic vegetation zone of the three. Typical areas that are mowed are levees, parks, and surrounding residential communities. Within the parks and residential communities, ornamental plants like monkey grass (*Liriope muscari*), hydrangea, rhododendrons, dogwood (*Cornus*), crabapple (*Malus*), Japanese maple (*Acer palmatum*), etc. can be found.

Fisheries and Wildlife Resources

Insects associated with open water and emergent habitats within TWT project area include true flies (order Diptera), mayflies (order Ephemeroptera), Caddisflies (order Trichoptera), Dragonflies and Damselflies (order Odonata), and Beetles (order Coleoptera). Many species of reptiles and amphibians inhabit the riparian bottomland forests and emergent wetlands along the Arkansas River, with amphibians being more prevalent in the bottomland swamp areas and other aquatic habitats. Bird species commonly found in forested habitats surrounding the study area include Pileated Woodpecker (*Dryocopus pileatus*), Belted Kingfisher (*Ceryle alcyon*), Wood Duck (*Aix sponsa*), Herons and Egrets (*Ardea* spp. and *Egretta* spp.), Barred Owl (*Strix varia*), and Red-shouldered Hawk (*Buteo lineatus*). Birds common in the wetland areas are similar to those that occur in upland forested habitats, particularly waterfowl such as Herons, Egrets, and Cormorants (*Phalacrocorax* spp.).

A seasonal fisheries survey of the study area conducted by Oklahoma Department of Wildlife Conservation biologists from October 2006 through September 2007 reported the occurrence of 41 species of fish in 12 families (Cherokee CRC, 2009). Of these reported species, four are listed as invasive exotics: grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), white perch (*Morone americana*), and flathead catfish (*Pylodictis olivaris*). The families represented by the most species were sunfish (*Lepomis* spp.); with nine species, carp (family Cyprinidae) and minnows (eight species), and suckers (seven species). The principal sport fish collected included largemouth bass (*Micropterus salmoides*), spotted bass (*Micropterus punctulatus*), striped bass (*Morone saxatilis*), channel catfish (*Ictalurus punctatus*), flathead catfish, white crappie (*Pomoxis annularis*), a variety of sunfish, and sauger (*Sander canadensis*). Recent occurrences (2015) of paddlefish (*Polyodon spathula*) in the Arkansas River in Tulsa County have also been reported. Numerous paddlefish were observed in pools below Zink Dam in late summer and early fall 2015, following elevated river stages throughout most of the summer, which likely allowed the paddlefish to travel farther upstream than during typical river stages.

Overall native fish populations have been adversely impacted from the construction of Keystone Dam through a combination of the changes in flows and the introduction of non-native game fish which better tolerate the altered aquatic ecosystem following the construction of Keystone Dam. Wetland and open water nursery habitats for juvenile fish have been reduced from periods of desiccation followed by higher flows, which destabilize wetland soils and vegetation strata. Introduced game fish species are more tolerant of the altered in-stream aquatic habitats (USACE and TVA, 2009).

Appendix B of Arkansas River Corridor Feasibility Report and Integrated Environmental Assessment (USACE and Tulsa County, 2018) notes that the most common aquatic macroinvertebrate species collected were midges (*Chironomids*), dragonflies and mayflies (*Naiads*), amphipods (*Hyalellans*), and water fleas (*Daphnia*). Freshwater mussels with the potential to occur within the action area of the Arkansas River and its tributaries include white heelsplitter (*Lasmigonia complanata*), fragile papershell (*Leptodea fragilis*), giant floater (*Pyganodon grandis*), pink papershell (*Potamilis ohiensis*), and mapleleaf (*Quadrula quadrula*) (Eagle Environmental Consulting, Inc., 2008). However, according to the USGS Nonindigenous Aquatic Species database, there is also an established (reproducing and overwintering) population of Zebra Mussels (*Dreissena polymorpha*) in the Polecat Snake Watershed as well as downstream within the Arkansas River Corridor (ODWC, 2012).

Invasive Species

An invasive species is defined as a plant or animal that is non-native (or native nuisance) to an ecosystem and whose introduction causes, or is likely to cause, economic and/or environmental harm, or harm to human health. Invasive species can thrive in areas beyond their normal range of dispersal. These species are characteristically adaptable, aggressive, and have high reproductive capacity. Their vigor, along with a lack of natural enemies or controls, often leads to outbreak populations with some level of negative effects on native plants, animals, and ecosystem functions and are often associated with disturbed ecosystems and human activities.

Table 2-2 lists many of the invasive and exotic species found within the TWT project area. Other species are currently being researched for their invasive characteristics, while there may be debate on whether other species should be considered invasive.

Table 2-2: Invasive Species in the Project Area

Habitat	Common Name	Scientific Name	Prevalence
Plants			
Aquatic	Giant Reed	Arundo donax	Moderate
Terrestrial	Johnson Grass	Sorghum halepense	Major
Animals			
Aquatic	Zebra Mussel	Dreissena polymorpha	Moderate
Terrestrial	Feral Cat	Felis catus	Moderate
Aquatic	Armored Catfish	Hypotomus plecostomus	Minor
Aquatic	Grass Carp	Ctenopharyngodon idella	Moderate
Aquatic	Common Carp	Cyprinus carpio	Moderate
Aquatic	White Perch	Morone americana	Moderate
Aquatic	Flathead Catfish	Pylodictis olivaris	Moderate
Birds			
Terrestrial	House Sparrow	Passer domesticus	Minor
Terrestrial	European Starling	Sturnus vulgaris	Minor
Terrestrial	Brown-headed Cowbird	Molothrus ater	Minor
Insects			
Terrestrial	Fire Ant	Solenopsis invicta	Major

Other invasive animals include red imported fire ants (*Solenopsis invicta*), house sparrows (*Passer domesticus*), European starlings (*Sturnus vulgaris*), and mollusks including zebra mussels (*Dreissena polymorpha*). Although native, cowbirds (*Molothrus ater*) have become problematic due to their expanding range associated with agriculture and human development. The close proximity to urban landscaping has led to many common landscape plants becoming aggressive colonizers throughout the state.

FWOP: Natural resources present in the study area are expected to persist in the future particularly those adapted to residential and urban areas like starlings and ornamental plants. Species that do not tolerate human disturbance have likely left the area, seldom visit the area, or utilize the areas behind the levees during early morning and overnight hours to avoid human disturbances. Natural vegetation has already largely been removed or altered except for the narrow strip of riparian forest between the levees and the Arkansas River.

2.2.10 Threatened and Endangered Species

The purpose of the Endangered Species Act is to provide protection for Endangered and Threatened Species. Protection is not limited to the species itself but also to the ecosystems upon which they depend on for survival. USFWS is the primary agency responsible for implementing the Endangered Species Act, and is responsible for birds and other terrestrial and freshwater species. USFWS responsibilities under the Endangered Species Act include (1) the identification of threatened and endangered species; (2) the identification of critical habitats for listed species; (3) implementation of research on, and recovery efforts for, these species; and (4) consultation with other Federal agencies concerning measures to avoid harm to listed species.

An endangered species is a species officially recognized by USFWS as being in danger of extinction throughout all or a significant portion of its range. A threatened species is a species likely to become endangered within the foreseeable future throughout all or a significant portion of its range. Proposed species are those that have been formally submitted to Congress for official listing as threatened or endangered. Species may be considered eligible for listing as endangered or threatened when any of the five following criteria occur: (1) current/imminent destruction, modification, or curtailment of their habitat or range; (2) overuse of the species for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or human-induced factors affecting their continued existence.

In addition, USFWS has identified species that are candidates for listing as a result of identified threats to their continued existence. The candidate designation includes species for which USFWS has sufficient information to support proposals to list as endangered or threatened under the Endangered Species Act. Until the species has gone through the entire review process it will not be listed as either endangered or threatened. Although not afforded protection by the Endangered Species Act, candidate species may be protected under other Federal or state laws.

The USFWS Information for Planning and Consultation (IPaC) database (2019) lists the threatened and endangered species that may occur within the project area (see USFWS Official Species List in Appendix E 3).

Based on the habitat requirements of listed species, the likelihood of listed species occurring within the study's action areas was evaluated based on existing habitat conditions and species distribution during informal consultation with USFWS. Table 2-3 lists Federally Threatened and Endangered Species that may occur in the region, and the likelihood that they occur within the study area. Species descriptions are provided in Table 2-3 as well.

Interior Least Tern

The interior least tern is the smallest of the species in the tern family (*Sternidae*). The U.S. Fish and Wildlife Service (USFWS) (1985A) lists the interior population of the least tern as endangered, but as of June 2019, USFW has not designated critical habitat for the least tern (USFWS, 2019D). Tulsa County is in the probable migratory path for least terns and provides stopover habitat. Since 2005, USACE Tulsa District has annually monitored least terns in the Arkansas, Canadian, and Red rivers in accordance with the USFWS 2005 Biological Opinion on the effects of USACE multipurpose projects. Least terns annually use the Arkansas River and associated sand bars for foraging and nesting within the study area.

Table 2-3: Federally Listed Threatened & Endangered Species with Potential to Occur Within the Study Area

Name	Scientific Name	Federal Protection Status	Occurrence within the Project Area
Birds			
Interior Least Tern	*Sterna antillarum athalassos*	Endangered	Common
Piping Plover	*Charadrius melodus*	Threatened	Rare
Red Knot	*Calidris canutus rufa*	Threatened	Rare
Whooping Crane	*Grus americana*	Endangered	Rare
Insects			
American Burying Beetle	*Nicrophorus americanus*	Endangered	Rare
Rattlesnake-master Borer Moth	*Papaipema eryngii*	Candidate	Rare
Mammals			
Northern Long-eared Bat	*Myotis septentrionalis*	Threatened	Rare

Least terns nest in colonies on barren to sparsely vegetated sand and gravel bars in braided streams and rivers, as well as on man-made structures such as inland beaches, wastewater treatment plants, and gravel mines. The terns prefer open, unobstructed areas rather than thick

vegetation. The forage fish base for least terns is typically most abundant in shallow, flowing riverine habitats. Additionally, least terns tend to forage no farther than about two miles from their nest sites, although some may fly up to four miles to fish (USFWS, 1990).

The distribution of least terns began to decline in the early 1900s due to widespread alteration of its riverine habitat (USFWS, 1990). Much of the sandbar habitat was compromised by stream channelization, irrigation, and the construction of dams such as Keystone. Keystone Lake traps the sediments that would maintain downstream island habitat for least terns leading to a decline in the quantity of sandbars suitable for least terns (USACE and TVA, 2009).

While the species continues to breed in river systems such as the Arkansas River, its distribution has become more restricted due to widespread alteration of its riverine habitat (USFWS, 1990). The manipulation of river flow can destroy or alter sandbars, preventing the creation of new river island habitat. Increased flow can wash away nests and chicks, and sand mining within the Arkansas River Corridor has removed least tern habitat. The Keystone Dam has also reduced scouring stream flows and allowed for the encroachment of vegetation on sandbars, reducing the quality of the habitat for least tern nesting despite efforts to clear the vegetation annually.

Low flows during the nesting season (approximately April to August) contribute to terns nesting at lower elevations, which increases the potential for those nests to be flooded during periods of higher flows. Lower flows result in land bridging which increases predator access to least tern nests.

Piping Plover

The piping plover is a migratory shorebird listed as endangered in the watershed of the Great Lakes and threatened in the remainder of its range (the Northern Great Plains, Atlantic coast, Gulf coast, Bahamas, and West Indies) (USFWS, 1985B). USFWS (2018A) identifies Tulsa County as “situated within the probable migratory pathway between breeding and winter habitats [of the Northern Great Plains population], and contain[ing] sites that could provide stopover habitat during migration.” The Northern Great Plains population of piping plover spends up to 10 months a year on its wintering ground along the Gulf coast and arrives on prairie breeding grounds in early May. During migration periods, they utilize large rivers, reservoir beaches, mudflats, and alkali flats (Haig, 1986; Schwalbach, 1988). They feed on a variety of aquatic and terrestrial invertebrates. The sandbars and bare gravel islands along the Arkansas River within the study area could provide suitable habitat during the plovers’ spring and fall migrations (USFWS, 2011).

Red Knot

The red knot is a migratory shorebird listed as threatened wherever found (USFWS, 2018A). Although sightings are rare, Tulsa County is listed as a location where the red knot is “known or believed to occur” and is located within the probable migratory path, between breeding in the

Arctic tundra and winter habitats in the southern United States and Central and South America (USFWS, 2019C). Red knots forage along sandy beaches and mud flats, and this species may use the study area for temporary stopover and foraging. The sandbars and bare gravel islands along the Arkansas River within the study area could provide suitable habitat during the red knot's spring and fall migrations.

Whooping Crane

Whooping crane (Grus Americana) is white, tall, has black legs and a reddish black head. It is a crane who's habitat consists of marshes, shallow lakes, lagoons, salt flats, grain and stubble fields, and barrier islands (AOU 1983, Matthews and Moseley 1990) and (NatureServe 2018A). Autumn migration normally begins in mid-September flying from Wood Buffalo National Park in central Canada, with most birds arriving on the wintering grounds at Aransas National Wildlife Refuge between late October and mid-November. Spring migration occurs during March and April. It has a diverse diet consisting of crabs, snails, fish, frogs, lizards, worms, insects, berries, grains, and acorns. Lakes, ponds, and other open water bodies in north central Oklahoma may be briefly used as stopover habitat by whooping crane.

American Burying Beetle

The American burying beetle is a member of the family Silphidae (carrion, or burying beetles) that is listed Endangered with a proposed rule to reclassify it to threatened (USFWS, 2019A). It is the largest species of *Nicrophorus* in North America. Existing populations of this species includes eastern Oklahoma and the study area. The presence of the species has been documented in Tulsa County within the last 15 years (USFWS, 2010). The American burying beetle is known to inhabit level areas in grasslands, grazed pastures, bottomland forest, open woodlands, and riparian areas. Wetlands with standing water or saturated soils and vegetation typical of hydric soils and wetland hydrology are listed by USFWS (2014) as unfavorable habitats. American burying beetles are habitat generalists; however, it is thought that undisturbed habitat and the availability of carrion is the most likely influence on species distribution (USFWS 1991).

Rattlesnake-master Borer Moth

USFWS lists the rattlesnake-master borer (*Papaipema eryngii*) moth as a Candidate species wherever found (USFWS 2019F). It is only known to occur in habitat where its sole food source, the rattlesnake-master (*Eryngium yuccifolium*) is found. There is only one known population of the rattlesnake-master borer moth in Oklahoma, and that is at the Nature Conservancy's Tallgrass Prairie Preserve, in Osage County, Oklahoma (USFWS 2013). The Tallgrass Prairie Preserve is approximately 50 miles from the Arkansas River. It is therefore very unlikely that the rattlesnake-master borer moth will occur in the project area due to a lack of habitat in the mostly urbanized study area.

Northern Long-eared Bat

USFWS lists the northern long-eared bat threatened wherever it is found (USFWS, 2019B). It was federally listed in 2015 following studies that revealed a decline in populations from the spread of white nose syndrome. USFWS service lists Tulsa County as a location where northern long-eared bats occur (USFWS, 2019B). Most northern long-eared bats seasonally migrate between winter hibernacula and summer maternity or bachelor colonies. Roosting may take place in tree bark, tree cavities, caves, mines, and barns. Northern long-eared bats forage along forested hillsides and ridges near roosting and hibernating caves. They emerge at dusk and feed on various insect species such as moths, flies, leafhoppers, caddisflies, and beetles from vegetation and water surfaces (USFWS, 2019B). Few large patches of forest occur in the study and no known caves exist in the area. With limited habitat, and the study area occurring on the fringe of the Northern long-eared bat's range, they are not expected to occur in the study area.

Oklahoma Natural Heritage Inventory

The Oklahoma Natural Heritage Inventory (ONHI), administered by ONHI, manages and disseminates occurrence of information on rare species, native plant communities, and animal aggregations in Oklahoma to help guide project planning efforts. An official request via email was made requesting this information for the TWT project area. In the inventory given to USACE ONHI indicates that there are two Federally endangered, threatened, and protected species that are known to occur in the project area, interior least tern (*Sternula antillarum athalassos*), and bald eagle (*Haliaeetus leucocephalus*).

In affording a specific species protection, the USFWS and National Marine Fisheries Service (NMFS) may list them as endangered, threatened, listed, migratory, and or protected. A species can have more than one protection measure with the exclusion of endangered, threatened, and listed. A species cannot be both endangered and threatened; however, a species can be endangered, migratory and protected.

- Endangered means that the USFWS and NMFS have determined that the species has a high chance of becoming extinct from the wild in the foreseeable future. Under this protection measure, a species cannot be taken, essential habitat altered and destroyed, nor transported without a permit. Take means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct" (USFWS, 2018B).
- Threatened means that USFWS and NMFS have determined that there is a low but probable chance of it becoming extinct from the wild in the foreseeable future. Under this protection measure, a species cannot be taken, essential habitat altered and destroyed, nor transported without a permit.
- Listed means that the USFWS and NMFS are currently reviewing the species protection status on whether to list it as threatened or endangered.

- Protected means that there are other Federal laws and regulations protecting the species than the Endangered Species Act and Migratory Bird Treaty Act. Examples include Bald and Golden Eagle Protection Act, Lacey Act, and Migratory Bird Treaty Act. Just because a species is listed as migratory doesn't automatically qualify it as protected, it must be protected by more than one law.
- Migratory means it applies specifically to migratory birds. The law that governs these species is the Migratory Bird Treaty Act. Under this law "it is illegal to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts*, nests, or eggs of such a bird except under the terms of a valid Federal permit" (USFWS, 2018C).

FWOP: This resource is not expected to change significantly during the planning horizon of this project compared to the existing conditions. Almost no special status species are known to occur within the study area, especially within the levee-protected area, except for the least tern that forages and nests along the Arkansas River and adjacent lakes and ponds.

2.2.11 Cultural Resources

A review of the Oklahoma Archaeological Survey (OAS) maps and existing information indicates numerous previous cultural resource surveys have been conducted within 1 km of the TWT Levee system. Although some investigations included sub-surface testing, the review and subsequent discussions with the Oklahoma State Historic Preservation Office (SHPO), indicated that significant tracts of land within the study area remain un-surveyed.

Two previously recorded archaeology sites, eighteen previously recorded historic properties, and six historic districts are located within 1 km of the TWT Levees. Of the eighteen previously recorded historic properties within 1 km of the TWT Levees, two are located in levee-protected areas. Located behind Levee A, the Sand Springs Power Plant was built in 1933 and was determined eligible for listing in the NRHP in 1998 under Criterion A for its association with community planning and development. Located behind Levee C, Cities Service Station #8 was built ca. 1940 and was determined eligible in 2011 under Criteria A and C for its association with the historic Route 66.

A formal determination of eligibility has not been made for the TWT Levees. Constructed between 1935 and 1945, the trapezoidal earthen levees provided the first significant protection from flooding along the Arkansas River in this region. Intensive cultural resource surveys, which will be conducted during the preconstruction, engineering, and design phase per the programmatic agreement, will include an assessment of the TWT Levees to determine their NRHP eligibility. For more information about cultural resources, see Appendix I.

FWOP: This resource is not expected to change significantly during the planning horizon of this project compared to the existing conditions. Without substantial levee repairs and improvements, the levee system will continue to degrade and some NRHP resources protected by the TWT levee system could be at increased risk of flood damage.

2.2.12 Land Use, Recreation, and Transportation

Land Use

Land use in the project area reflects the industrial history of the Arkansas River and includes the TWT Levee System, Zink Dam, multiple large refineries, steel mills, and rail/oil/ gas pipeline corridors as well as active sand-mining in the Arkansas River itself. A land use inventory performed in 2005 of the Arkansas River and a 0.5-mile buffer on either side of the center of the river from Keystone Dam southward to the Tulsa-Wagoner county line (study area), found that over one-third was used for cropland and pasture. Almost a quarter of the land in the area was in some type of developed use such as residential or industrial (Guernsey, C.H. and Company, 2005). Prime farmlands are also present in the study area, as defined by the U.S. Department of Agriculture (USDA); however, they tend to be more prevalent in the southern extent. The most recent soil survey for Tulsa County found that approximately 126,000 acres, or 34 percent of the county, meets the requirements for prime farmland (USDA, 2000).

Lands adjacent to the project area are generally a mix of forests and woodlands, introduced and semi natural vegetation, urban, suburban, and industrial use. Just upstream, or west, of the Hwy 97 Bridge on the northern side of the river are the Sand Springs River City Park and Case Community Center, which are described in the recreational resource section. Downstream and east of the Hwy 97 Bridge, the northern bank becomes substantially more developed with the Sand Springs Petrochemical and Sheffield Steel Company (now closed) sites as well as the Sand Springs Water Treatment Plant at West 21st Street. The Sand Springs Sand and Gravel Company, located on the southern side of the river just upstream of the Hwy 97 Bridge is one of three sand mining operations in the study area. The balance of the southern side of the river just downstream of the bridge is initially less developed, though paralleled by the Avery Drive/Burlington Norfolk Southern Railroad corridor. Lands directly adjacent to the project area are primarily zoned for agriculture or industrial uses, with the exception of a residential single family area near West 14th Street and a mix of commercial, single family, and multi-family residential areas just south of the intersection of Highway 97 and the railroad corridor (INCOG, 2013).

Recreation Resources

The study area offers a range of existing water-based and land-based recreational opportunities. Within the study area, recreation is managed by three separate public agencies: the River Parks Authority (RPA), the City of Tulsa Parks Department, and the Tulsa County Park Department. RPA, which is a public trust created by the City of Tulsa and Tulsa County, which manages and oversees the River Parks system of approximately 800 acres of land, including 41 miles of riverfront within the study area.

The Arkansas River, and Zink Dam tailrace areas in particular, are popular destinations for fishing, while River City Park in Sand Springs offers a boat ramp on the northern side of the river, and River West Festival Park offers a boat ramp on the south side with fair grounds. All throughout the project area there are community playgrounds & pools, and private and public golf courses.

The wooded areas along the river within the vicinity of the study area provide public-access recreational opportunities in multiple parks and recreation sites with various amenities: picnic grounds, fountains, water splash pads, bicycle-rentals, skateboarding ramps, playgrounds, gathering plazas, parking, arts, restrooms, and a disc golf course. Zink Lake is located near the center of the study area near 29th Street downstream of the study area, and is the only existing impoundment. It is used for non-motorized boating, primarily rowing, with a public boat ramp offered at the River West Festival Park; however, “primary body contact” water activities such as swimming are prohibited. The “Tulsa Wave” offers kayaking opportunities downstream of Zink Dam on the western bank (RPA, 2016). The popular Riverside Drive trails on the northern and eastern side of the river include a total of 30 miles of paved recreational trails that connect the study area to downtown, through neighborhoods, and to the nearby communities of Sand Springs, Jenks, Broken Arrow, and Bixby. In the study area, the Pedestrian Bridge, which was formerly used by the Midland Valley Railroad, spans the river’s 1,400-foot channel at 29th Street and Riverside, creating pedestrian/cyclist access from the eastern side of the river to the western side.

Transportation

There are three major highways transecting the study area. The Mingo Valley Expressway (at S. 71st Street) in southern Tulsa County has the highest daily traffic count, followed by Interstate 44. U.S. Highway 64 roughly parallels the northern side of the Arkansas River from Keystone Dam to its intersection with Interstate 44. The study area is crossed, going downstream, by Hwy 97 (Wilson Avenue), Interstate 244, Southwest Boulevard, West 23rd Street, Interstate 44, Mingo Valley Expressway, Creek Turnpike, Broken Arrow Expressway, and U.S. Highway 64 in southeastern Tulsa County. Due to its extensive history with refining, there are multiple rail lines crossing the study area. Burlington Northern Santa Fe (BNSF) is the major rail carrier in the county and tends to carry coal, agricultural and forest products, chemicals, metals, and consumer goods. Union Pacific Railroad Road (UPRR) operates over the old Midland Valley line which parallels the Broken Arrow Expressway. The Tulsa-Sapulpa Union Railway is a Class III short line railway operating between Tulsa and Sapulpa and between Tulsa and Jenks.

FWOP: Resource has potential to significantly change during the planning horizon of the proposed project in the event of increased flooding compared to existing conditions due to levee degradation. The levees will continue to degrade, meaning increased risk for property land use, transportation infrastructure, and recreation features within the levee protected areas. Erosion and increased inundation of levee-protected lands could alter usability in the future.

2.2.13 Socioeconomics (Demographics, Environmental Justice and Visual Aesthetics)

Demographics

As shown in Table 2-4, the study area was home to 6,329 people in year 2000 with most residing in Levee Area B (90 percent). Since then population in both areas has declined (a 17 percent reduction in Area A and a 9 percent decline in Area B). In contrast, population for the City of Tulsa, Tulsa County, Oklahoma and the U.S. have all increased substantially. At the state and county level, population projections indicate robust growth over the long-term. According to the Oklahoma Department of Commerce, Oklahoma's population will reach 4 million by 2020, and top 5.5 million by 2075. The number of people living in Tulsa County is expected to grow from roughly 640,000 in 2019 to 934,000 in 2075. Population projections for the study area are not available; however, it is unlikely that population levels will increase in the future based on historical trends.

Table 2-5 summarizes age distribution for the study area. Overall, trends follow regional and national patterns with the exception of elderly residents, which comprise a higher percentage in the study area.

Table 2-4: Population Estimates for Study Area, Region and Nation

Geographical Area	2000	2010	2019	Percent Change (2000-2019)
Levee Area A	631	513	522	(-17%)
Levee Area B	5,698	5,134	5,201	(-9%)
Total Study Area	6,329	5,647	5,723	(-10%)
Tulsa (City)	392,752	391,900	411,490	+5%
Tulsa County	563,299	603,403	657,000	+17%
Oklahoma	3,450,654	3,751,351	4,031,901	+17%
United States	281,421,906	308,745,538	332,417,793	+18%

Source: U.S. Census (2000, 2010); ESRI Demographic Data Mapper (2019)

Table 2-5: Age Distribution of Population for Study Area, Region and Nation

Geographical Area	9 or less	10 to 14	15 to 24	25 to 34	35 to 44	45 to 54	55 to 64	65 to 74	75 or more
Levee A	14.5%	5.5%	11.4%	11.1%	12.3%	10.7%	14.0%	12.1%	8.4%
Levee B	13.3%	6.9%	10.2%	12.1%	11.0%	10.3%	13.0%	14.3%	8.9%
Tulsa (City)	13.1%	6.4%	12.4%	15.0%	12.5%	9.5%	12.0%	11.0%	7.8%
Tulsa County	13.5%	6.7%	12.9%	14.5%	13.0%	12.0%	12.2%	8.9%	6.3%
Oklahoma	12.9%	6.4%	13.1%	13.9%	12.4%	11.8%	12.8%	9.8%	6.8%
United States	12.1%	6.3%	13.0%	14.0%	12.6%	12.5%	13.1%	9.7%	6.7%

Source: U.S. Census (2000, 2010); ESRI Demographic Data Mapper (2019)

Environmental Justice

Executive Order 12898, entitled “Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations (1994),” addresses disproportionate human health and environmental impacts that a project or plan may have on minority or low-income communities. Thus, the environmental effects of a plan on such communities including Native American populations must be disclosed, and agencies must evaluate projects to ensure that proposed actions do not disproportionally impact minority or low income communities. If such impacts are identified, appropriate mitigation measures must be implemented.

To determine whether a project has a disproportionate effect on potential environmental justice communities (i.e., minority or low income population), the demographics of an affected population within the vicinity of a project must be considered in the context of the overall region. Guidance from the Council on Environmental Quality (CEQ) states that “minority populations should be identified where either: (1) the minority population of the affected areas exceeds 50 percent, or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis (CEQ 1997).”

Table 2-6 displays Census data summarizing racial characteristics of areas adjacent to plan construction sites. The purpose is to analyze whether the demographics of the affected area differ in the context of the broader region; and if so, do differences meet CEQ criteria for an Environmental Justice community. Based on the analysis, it does not appear that minorities in the study area are disproportionately affected; however, it is possible that the study area may qualify as a low income population.

Reported household incomes, both per capita and median, for the study area are substantially lower than regional and national values (Figure 2-3). Per capita and median household income in Area A are $25,273 and $12,336 and for Area B $30,499 and $15,342 respectively. The percent of households living below the federal poverty level is about 19 percent in Area B and 21 percent in Area A. In contrast, nearly 11 percent of U.S. and 12 percent of Oklahoma and Tulsa County households live below the poverty line (Table 2-7).

Any alternative selected that has the potential to disproportionately, adversely impact low income and/or minority populations would require additional analysis to fully understand the socioeconomic impacts to these communities. Further community engagement, to include but not limited to surveys and information meetings could also be required.

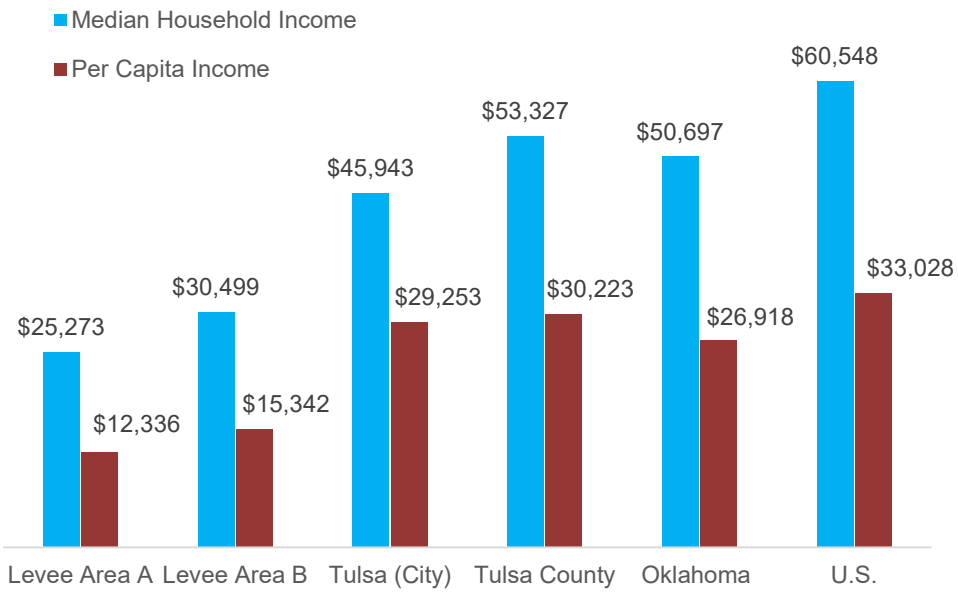

Figure 2-3: Median Household and Per Capita Income in the Study Area, Region and U.S. Source: U.S. Census Bureau

Table 2-6: Racial Composition for Study Area and Region and Nation

Race	Levee Area A		Levee Area B		Tulsa (city)	
	Number	Percent	Number	Percent	Number	Percent
White	313	60.0%	3,401	65.4%	1,010	43.2%
Black	59	11.3%	343	6.6%	699	29.9%
American Indian and Alaskan Native	72	13.8%	713	13.7%	220	9.4%
Asian	4	0.8%	26	0.5%	56	2.4%
Native Hawaiian or Pacific Islander	0	0.0%	5	0.1%	2	0.1%
Some other race alone	18	3.4%	255	4.9%	122	5.2%
Two or More Races	56	10.7%	468	9.0%	227	9.7%
Total	522	100%	5,201	100%	2,339	100%
Hispanic Origin	41	7.9%	520	10.0%	330	14.1%
	Tulsa (county)		Oklahoma		U.S.	
White	431,649	65.7%	2,786,044	69.1%	231,362,784	69.6%
Black	68,985	10.5%	306,424	7.6%	42,881,895	12.9%
American Indian and Alaskan Native	41,391	6.3%	350,775	8.7%	3,324,178	1.0%
Asian	24,309	3.7%	96,766	2.4%	19,280,232	5.8%
Native Hawaiian or Pacific Islander	657	0.1%	8,064	0.2%	664,836	0.2%
Some other race alone	46,647	7.1%	209,659	5.2%	23,269,246	7.0%
Two or More Races	43,362	6.6%	274,169	6.8%	11,634,623	3.5%
Total	657,000	100%	4,031,901	100%	332,417,793	100%
Hispanic Origin	88,038	13.4%	455,605	11.3%	61,829,709	18.6%

Source: U.S. Census and ESRI Demographic Data Mapper

Table 2-7: Poverty Status for Study Area and Region and Nation

Region	Percent of households below federal poverty line	Unemployment rate
Levee Area A	21.7%	15.3%
Levee Area B	19.3%	11.1%
Tulsa (county)	11.8%	5.0%
Oklahoma	11.8%	4.8%
U.S.	10.5%	4.6%

Source: Bureau of Labor Statistics (2017 values) and U.S. Census Bureau American Community Survey 2017`

Visual Aesthetics

The visual resources of the study area refer to those components of the environment perceived through the visual sense only, while aesthetic resources specifically refers to beauty in both form and appearance (Army, 2006). Due to the intensity of adjacent land uses, these resources are also informed by the natural resources, land use, and recreation sections of this document. Considered a “prairie river,” the undeveloped portions of the Arkansas River corridor include a mix of woodlands and grasslands and more open areas with cottonwoods, willows, sedges, and rushes. However, the visual and aesthetic character of the study area has been substantially changed due to its long history of use for navigation and trade. The visual and aesthetic character of the study corridor varies and is described via the three sub-reaches used in the 2005 Master Plan (INCOG 2005). This plan calls for various development along the Arkansas River to include residential, commercial, recreational, and ecosystem restoration features. Notable visual and aesthetic features within the study area includes, views of from River City Park and State Highway 97.

FWOP: Socioeconomic resources are not expected to change significantly during the planning horizon of this project within the study area compared to the existing conditions. Current flood risk and industrial land use could be limiting some development from occurring within the study area. As such, little opportunity exists for new job development outside of industrial work to occur within Levees A and B.

2.2.14 Utilities

The TWT study area is crossed by two major interstates, I-244, and I-44, as well as bridges at State Highway 97 (within the study area), and 23rd Street. A dense network of utilities is present throughout most of the corridor and includes distribution systems for electricity, water, and natural gas. A railroad corridor parallels the entire southern/western side of the river (BNSF Railway/Midland Valley/Missouri Pacific), while a rail spur parallels the northern bank of the river from Sand Springs downstream to tie in to a rail corridor that generally follows I-244. Numerous power transmission lines and oil/gas pipelines traverse the area supporting corresponding operations along the river (Guernsey, C.H. and Company, 2005). This includes several gas pipelines that crosses the river within the project area approximately 2 miles west of the Hwy 97 Bridge, while a large electrical transmission line crosses the river just east of the bridge near the confluence of Prattville Creek (CH2M Hill, 2009).

The City of Tulsa has two water treatment plants that supply drinking water to more than 139,600 metered accounts in the city and more than 500,000 people in the Tulsa metropolitan area (City of Tulsa, 2017A). The Environmental Operations Division of the Public Works & Development Department operates the city's water supply lakes, water treatment plants, and water pipelines. There are seven wastewater treatment facilities with their corresponding collection systems within the project area. The City of Tulsa wastewater treatment system includes four treatment plants: Northside, Southside, Haikey Creek, and Lower Bird Creek (City of Tulsa, 2017B). The City of Bixby also provides wastewater services via the Bixby North and South Lagoons; the City of Bixby plans to remove the Bixby North Lagoons and to either convert the Bixby South lagoons into a Waste Water Treatment Plant (WWTP) or decommission the lagoons. Additionally, the Haikey Creek WWTP is located just south of East 151st South Street on the north side of the river.

Within the vicinity of the flow regime and Prattville Creek restoration measures are two industrial and one municipal waste water treatment facilities. The Sand Springs WWTP treats nearly all of the city's wastewater and has a capacity of 3.1 million gallons per day, while the lagoon system has a capacity of 50,000 gallons per day. As mentioned earlier, an existing Public Service Company (PSO) electrical transmission corridor (200 to 300 feet wide) crosses the River approximately 2000 feet downstream of the bridge. Related, supporting PSO infrastructure includes a tower in the river 2,300 feet downstream of the Highway 97 bridge as well as a tower less than 100 feet from the southern bank of the Arkansas River and 200 feet from the western bank of Prattville Creek on the 4-H and FFA livestock area. The two PSO transmission towers that tie in on the northern side of the Arkansas River are located 500 to 600 feet from the top of its banks.

An extensive field investigation and survey performed in 2009 identified a total of 266 storm sewer outfalls and drainage structures located along the Arkansas River in the vicinity of the corridor study (Meshek and Associates, 2009). More recently, the 2015 Schematic Design and Cost Estimates Report located 159 adjacent outfalls within the project area and classified them

into three groupings: (1) those with inverts below the new pool elevations (18 total outfalls), (2) those with inverts within 2 feet of the new pool elevations (23 outfalls), and (3) those with invert elevation greater than 2 feet above the new pool (118 outfalls). There are 20 outfalls located between Keystone Dam and the downstream side of the Highway 97 Bridge; of these, three are below the proposed pool elevation of 638.00, three outfalls are within 2 feet of the pool, while the remaining 14 are more than 2 feet above pool elevation (CH2M Hill, 2015).

FWOP: Resource has potential to significantly change during the planning horizon of the proposed project in the event of increased flooding compared to existing conditions due to levee degradation. The levees will continue to degrade, meaning increased risk for damage to utility features within the levee protected areas. Erosion and increased inundation of levee-protected lands could adversely impact utilities in the future.

2.2.15 Health and Safety

This section describes the health and safety aspects of the study area by first characterizing the existing safety concerns associated with levees and then briefly describing potential health issues related to the Protection of Children under EO 13045. Due to historical incidents with the former reregulation dam as well as below Zink Dam during high river flows, public safety is one of the major design considerations for any new structure in and around the Arkansas River. While subsurface currents created below a dam are often responsible for accidents, the design of flow regime measures have improved greatly, allowing for a greater degree of public safety (Guernsey, C.H. & Company, 2005). Within the project area existing TWT Levees directly protects various industrial facilities neighborhoods, schools, and parks.

EO 13045 directs Federal agencies to analyze their policies, programs, activities, and standards for any environmental health or safety risks that may disproportionately affect children, including risks to health or safety that are attributable to products or substances that a child is likely to come in contact with or ingest, such as air, food, water, recreational waters, soil, or products they might use or be exposed to. As it relates to the study area, while there are multiple schools and daycare facilities along the corridor, “primary body contact” water activities such as swimming are currently prohibited.

FWOP: This resource has potential to significantly change during the planning horizon of the proposed project in the event of increased flooding compared to existing conditions due to levee degradation. Degrading flood risk management infrastructure will increase risk for both property and human life; damage to surrounding infrastructure such as roads, hospitals, etc., and may also decrease community health & safety. Continued community awareness, planning, and communication prior to and during flood events would be instrumental in avoiding life threatening situations.

2.2.16 Hazardous, Toxic and Radioactive Waste

In accordance with Resource Conservation and Recovery Act (RCRA), facilities that generate, transport, treat, store, or dispose of hazardous waste must provide information about their activities to state environmental agencies. There were over 100 waste sites identified by EnviroMapper located adjacent to Arkansas River within the project area. The types of waste that may exist in the proposed project area include those from facilities such as oil and petroleum industries, utilities, electronic manufacturing, rubber manufacturing, recycling, concrete services, automobile service centers and tire shops, and gasoline service stations (EPA, 2016d). Most of the sites were identified as RCRA sites. According to the 2014 Toxics Release Inventory (TRI), there were 19 RCRA facilities that had releases in 2014. There were two facilities, Petroleum Electronics Mfg, Inc. and Power Electronics Mfg. Inc., which were identified by EnviroMapper as Superfund facilities. Both facilities are located approximately 3.5 miles upstream of the Zink Dam.

In the vicinity of Levee A is the Webco Industry Star Center (pipe bending and fabrication) (permitted facility) with an individual National Pollutant Discharge Elimination System permit for noncontact cooling water that is in compliance (USACE Tulsa, 2016). The Mohawk Material-Ready-Mixed Concrete is also upstream from the site but doesn't have surface water discharges. There are several secondary nonferrous metal fabrication facilities along or near Levee A such as Sheffield Steel and GERDAU AMERISTEEL but none have permitted discharges to the river or storm drains.

An initial survey for HTRW sites was undertaken as part of this study in accordance with ER 1165-2-132 "HTRW in Civil Works Projects" (See Appendix H). The survey identified the Sand Springs Petrochemical Complex (SSPC), located adjacent to the north bank of the Arkansas River less than one mile below Highway 97. The SSPC site was listed on in the National Priority List (NPL in 1986. In 1995, potentially responsible parties dug up, stabilized and disposed of petroleum waste material in an onsite landfill. The landfill area associated with the site is 0.37 square miles (235 acres). EPA removed the site from the NPL in 2000 (EPA, 2016e). Between 2004 and 2006, parties dug up and removed sludge material along the banks of the Arkansas River. Operation and maintenance activities at the site continue. Fencing has been placed around the landfill, and operation and maintenance activities at the site continue today. A portion of the north bank of the Arkansas River has also had rip-rap placed (rock used to armor shorelines) to prevent erosion by the Arkansas River (ODEQ, 2016). A series of 5-year review for the SSPC found the remedies in place to be protective of human health and the environment.

In accordance with Emergency Planning and Community Right-To-Know Act of 1986 and Toxic Substances Control Act of 1976, facilities that release toxic substances into the environment are required to report such releases, including compliant and potentially noncompliant releases. Data regarding releases are maintained in the TRI database and contain information about more than 650 toxic chemicals that are being used, manufactured, treated, transported, or

released into the environment. Facilities identified in the database search conducted for this study may have reported one or more toxic releases, such as air emissions, water surface water discharges, releases to land, underground injections, or transfers to offsite locations. There were approximately 20 sites identified as toxic sites adjacent to the Arkansas River Corridor study area. Businesses included oil and petroleum facilities, concrete, steel, and chemical companies, as well as a cola bottling facility (EPA, 2016d).

FWOP: This resource has potential to significantly change during the planning horizon of the proposed project in the event of increased flooding compared to existing conditions due to levee degradation. Degrading flood risk management infrastructure could increase risk for exposure and distribution of subsurface contaminants.

2.2.17 Topography, Geology and Soils

Geology and Topography

The project area below Keystone Dam lies within the Osage Plains region of the Central Lowland physiographic province. The predominant landforms in Tulsa County are the Eastern Sandstone Cuesta Plain and the Claremore Cuesta Plain. The Claremore Cuesta Plain, located within the study area, produces gently sloping and frequent hills which form the topographic highs of the area. The Arkansas River forms the topographic lows within the study area. Local elevation ranges from 577 to 670 feet above mean sea level (amsl), as measured against the National Geodetic Vertical Datum of 1988 (Johnson et al., 1979). The Arkansas River bed elevation drops approximately 30 feet between Keystone Lake, upstream of the study area, and Zink Dam.

The regional geology provides context for the past and current geomorphic processes that shape the Arkansas River and floodplain. Rocks in the study area were formed from ancient river and sea deposits. Rock outcrops in the hills adjacent to the Arkansas River in the study area are of Pennsylvanian age and consist of Dewey Limestone and Nellie Bly Formation shale. Sediments washed into the region from the Rocky Mountains during the Tertiary. The broad Arkansas River floodplain is composed of Quaternary alluvium. The alluvium consists of unconsolidated gravels, sands, silts, and clays (Bennison et al., 1972; Marcher and Bingham 1988; Heran et al., 2003).

Soils, Including Prime Farmlands

As required by Section 1541(b) of the Farmland Protection Policy Act (FPPA) of 1980 and 1995, 7 U.S.C. 4202(b), federal and state agencies, as well as projects funded with federal funds, are required to (a) use the criteria to identify and take into account the adverse effects of their programs on the preservation of farmland, (b) consider alternative actions, as appropriate, that could lessen adverse effects, and (c) ensure that their programs, to the extent practicable, are compatible with state and units of local government and private programs and policies to protect farmland.

Table 2-8 shows the acreage and farmland status associated with each soil and surface type in the project area, and Figure 2-4 shows the location of each soil and surface type. The main soil series within TWT Project Area is the Choska-Severn-Urban land complex, 0 to 1 percent slopes, rarely flooded soil. Natural Resource Conservation Service (NRCS) classifies these two distinctly different soils together because they occur in geographically similar areas and for mapping purposes made things all that much more easier to read. The complex itself makes up 70.8 percent of surface types within the TWT Project. The Choska soil makes up 42 percent of the complex , occurs in 0-80 inch thick surface layers, normally found on flat areas, is well drained, and contains fine sandy to silty loam. Severn soil makes up 31 percent of the complex, occurs in a 0-80 inches thick surface layers, normally found on flat areas, is well drained, and contains Calcareous loamy and silty alluvium. The Urban soil makes up 22 percent of the complex, occurs in a 0-60 inches thick surface layers, and normally found on flat areas. And these soils are not prime farmland soils. The NRCS Web Soil Survey (2018) reports 5 soil types occurring within TWT Project Area.

The Choska-Severn soil series is the predominant soil series below Keystone Dam, according to the Natural Resources Conservation Service (NRCS) Soil Survey of Tulsa County, Oklahoma (Cole, 1977). These soils are characterized as deep, well-drained sandy to silty loam overlying loamy and sandy floodplain alluvium.

Widespread bank erosion is evident throughout the river corridor along the study area. The river banks throughout and upstream of the study area are generally sandy and highly erodible. The channel downstream of Keystone Dam has experienced incision and bank erosion as it has been scoured of sediment to regain the sediment load of the river that is trapped upstream in Keystone Lake. The rapid fluctuation in river flow has reduced native wetland habitats and has reduced the stability of rooted vegetation along river banks and increased erosion. This erosion would likely continue until the banks of the channel are armored.

The major changes in sandy substrate (sediment fluxes) in the corridor occur during high flow events when major sediment transport happens (USGS, 2011). The 2011 USGS report concluded that there has been an 82 percent documented reduction of sediment concentrations since the construction of Keystone Dam in 1964.

FWOP: These resources are not expected to change significantly during the planning horizon of this project compared to the existing conditions. The lands behind the levee protected areas are largely already disturbed.

Prime & Unique Farmland

Prime Farmland is a limited national resource recognized for its importance by the Unites States Department of Agriculture (USDA) and is delineated based on a national standard. Prime Farmland is defined by the USDA as land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is

available for these uses. Typically, prime farmlands are able to economically produce high yields of crops with proper management. The soil conditions usually experience favorable moisture, aeration, acidity, alkalinity, salt/sodium content, and is not typically inundated for long periods of time.

Prime farmland soil is the Choska very fine sandy loam, 0 to 1 percent slopes, rarely flooded soil.

Unique Farmland is land other than prime farmland used for the production of specific high-value foods and fiber crops like citrus, tree nuts, olives, etc. These lands have special soil conditions that provide the optimal cultivation environment to sustainably produce high yields of high-value crops. Unique farmland is not determined on a national criteria and is commonly found in areas of favorable microclimates like the wine country in California.

There is are not any known Unique farmlands within the TWT project.

FWOP: These resources are not expected to change significantly during the planning horizon of this project compared to the existing conditions. Most soils capable of supporting prime or unique farmlands have already been disturbed due to urbanization behind the levee system.

Table 2-8: Total Acres of Soil & Surface Types within the TWT Project

Map Unit Symbol	Soil Type	Number of Acres	Farmland Status
7	Choska very fine sandy loam, 0 to 1 percent slopes, rarely flooded	9.3	Prime
8	Choska-Severn-Urban land complex, 0 to 1 percent slopes, rarely flooded	179	Not Prime
27	Kiomatia loamy fine sand, 0 to 1 percent slopes, frequently flooded	55.4	Not Prime
48	Radley silt loam, 0 to 1 percent slopes, frequently flooded	4.8	Not Prime
54	Wynona-Urban land complex, 0 to 1 percent slopes, occasionally flooded	2.9	Not Prime
W	Water	1.7	Not Prime
	Total	253.6	

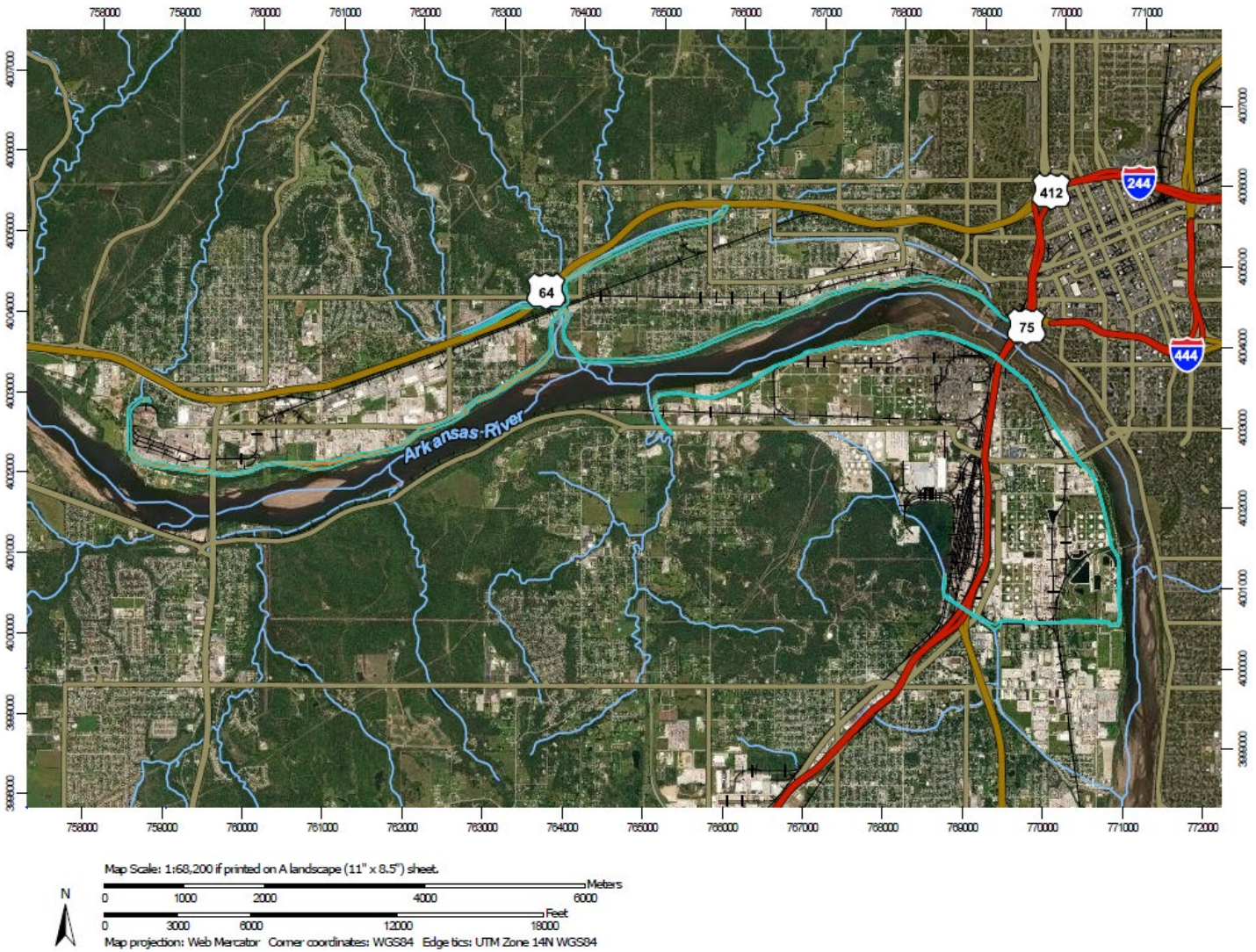

Figure 2-4: Soil Map TWT Project Area

CHAPTER 3: PLAN FORMULATION

Plan formulation and evaluation of alternatives for this study were conducted in accordance with the Planning Guidance Notebook (Engineer Regulation (ER) 1105-2-100); Economic and Environmental Principles and Guidelines for Water and Related Land Resources Planning Act (P.L. 89-80); Section 904 of the Water Resources Development Act of 1986 (33 U.S.C. §2281); 1983 Principles & Guidelines (P&G) which provides plans that address other Federal, State, and local concerns; and USACE Planning Bulletin (PB) 2019-04, Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies.

Based on guidance and policy, USACE has a well-defined six-step process used to identify and respond to problems and opportunities associated with civil works planning objectives:

- Identify problems and opportunities,
- Inventory and forecast conditions,
- Formulate alternative plans,
- Evaluate alternative plans,
- Compare alternative plans; and,
- Select recommended plan.

The remainder of this section describes each step of the process as it applies to this study.

3.1 Problems and Opportunities

The problem addressed is flood risk to life safety and property in areas behind the TWT levee system. TWT levee system could fail due to overtopping and flood loadings below the top of the levee that are caused by inadequately controlled under seepage and through seepage.

Under seepage and through seepage is river water that flows under and through a levee from a river during a flood. Generally, the water seeps through the levee where seepage reduction measures (relief wells, toe drains, etc.) are constructed to reduce water pressure and allow excess water to divert safely. Otherwise, water flows through the soil towards the dry side of the levee and erodes levee materials or foundation materials and results in sand boils that can destroy a levee if not addressed.

Opportunities exist to determine a long-term effective and environmentally sustainable solution to reduce risk of damages due to breach and non-breach flooding and life safety risks. An opportunity also exists to address non-breach and incremental risk through permanent flood risk management measures. In addition, there is an opportunity to support community resiliency.

3.2 Planning Objectives & Constraints

The overarching objective is to find an effective and environmentally acceptable solution to ensure a sustainable and resilient levee system, which reduces risk of damages and life safety. Each planning objectives applies to the study area for the 50-year period of analysis. Specific objectives are to:

- Reduce life safety risk; and
- Reduce property damages.

The following constraints (i.e., limitations on the range of formulated measures and alternatives) include:

- Avoid addressing seepage repair that affects hazardous materials at Levee A at Superfund site (EPA site);
- Avoid impacts to Arkansas River Corridor project;
- Avoid transfer of flood risk to communities outside the TWT Levee System;
- Minimize impacts to Endangered Species and the human environment; and
- Minimize impacts to navigation downstream.

3.3 Flood Risk Strategy

Flood risk is made up of a variety of factors, beyond exclusively the condition of the levees themselves including: the hazard, system performance, exposure, vulnerability, and consequences. The essential questions in determining flood risk are:

- What possible loading events (flood event and/or hazards) are there?
- How well will the levee system perform when the event occurs?
- What are the consequences if the levee does not perform as expected? What loss of life could occur?

In even simpler terms, flood risk is the **probability of a flood** multiplied by the **consequences of the flood**.

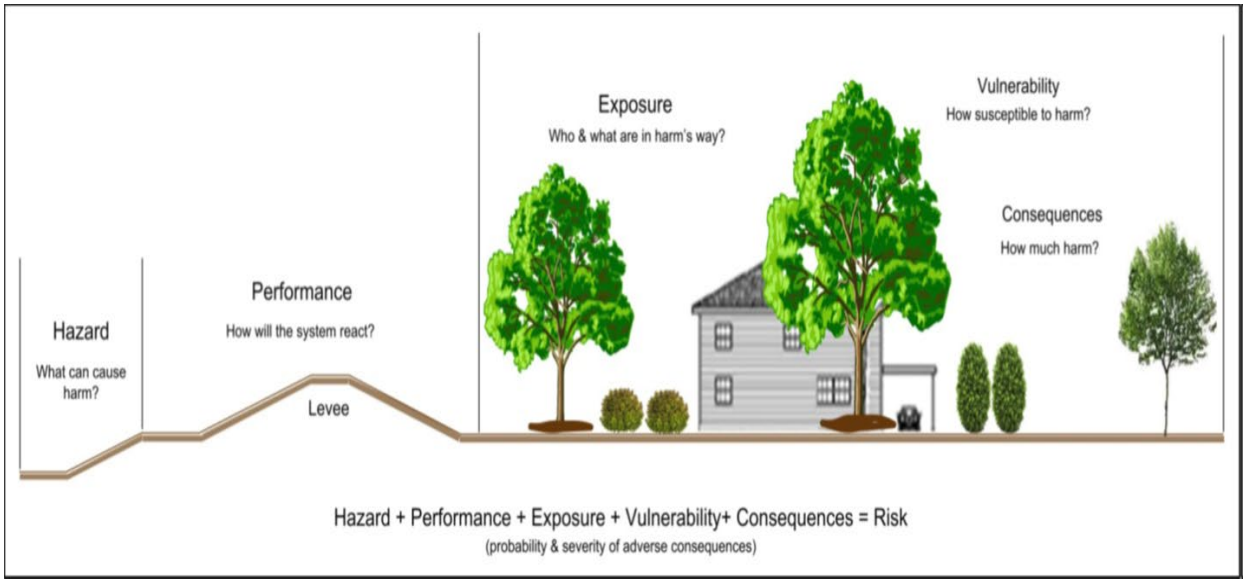

Figure 3.1: Flood Risk Factors

Chapter 2 described existing conditions and the Future without Project Condition (FWOP) of the TWT levee system. During formulation, the study team considered the FWOP condition and tried to answer the question, "What additional investments could lower the remaining life safety risk prior to overtopping to a level that meets the TRGs for individual and societal life safety?"

With this in mind, measures and alternatives were formulated to reduce life safety risk that occurs in existing and future conditions. Similarly, alternatives are evaluated and compared based on their ability to reduce remaining life safety risks related to overtopping and seepage, their ability to reduce remaining economic damages, their costs to reduce the remaining risks and damages, and other factors, as described in the following paragraphs.

Upon identification of the recommended plan for the remaining project features, the costs of this plan will be added to the previous project investments and an overall total project cost will be developed.

3.4 Formulating Alternative Plans

Section 3.4 assesses preliminary measures and alternatives based on ability to reduce flood and life safety risks. The team discussed the strategies for addressing flood risk and reconstruction of the system for system functionality and effectiveness. The next two sections discuss the formulation strategy and reconstruction.

3.4.1 Flood Risk Formulation Strategy

Reducing flood risk for a levee system can be accomplished via four general strategies:

1) Reduce flood hazards or loading on the system (i.e., lower the magnitude and likelihood of the hazard).
2) Improve performance or response of the system to the load (reconstruction of the system and add to or modify features of the levee system to address failure modes to promote system resilience and sustainability).
3) Reduce exposure of people and property at risk through approaches such as altering or limiting future development or relocating population away from a levee.
4) Reduce the vulnerability of people and property at risk through actions such as:
   a. Strengthening emergency action and evacuation plans,
   b. Improving warning systems,
   c. Improving roads and evacuation infrastructure,
   d. Enhancing building codes; and,
   e. Fostering effective response by households and businesses to such warnings, including vertical evacuation as appropriate.

Upon assessing the applicability and practicality of the four strategies, the study team arrived at several conclusions regarding each.

- **Strategy 1 (reduce hazard or load on the system):** The team concluded that there are limited viable measures to reduce loading on the levees given that the primary source of loading (Keystone Dam on the Arkansas River) is part of a highly regulated system, and substantial changes to flow regulation is not feasible.

- **Strategy 2 (improve performance or responsiveness of system)**: Improving the performance or response of the levee system and or reconstructing of the system could be addressed via structural measures, which are discussed in further detail in subsequent sections.

- **Strategy 3 (reduce exposure through land management)**: Given the extent of residential, commercial and particularly industrial development behind the levees, any measures to relocate populations and or structures would be costly and may be met with substantial resistance among business owners and residents. Nevertheless, the study team evaluated potential non-structural measures such as, buy-outs in further detail.

- **Strategy 4 (reduce vulnerability of at risk population):** After reviewing existing emergency response and evacuation plans, the team concluded that existing plans appeared to be highly effective, but decided to evaluate the plans during this study and

the recent Semi Quantitative Risk Assessment (SQRA) for Keystone Dam using HEC models (LifeSim) and in the context of lessons learned from the May 2019 flood event. Measures in the context of Strategy 4 were developed as non-structural measures.

In summary, the study team focused on structural measures that would involve reconstructing the system to address failure modes and improve system performance; and developed potential measures to reduce the vulnerability of the population at risk.

3.4.2 Reconstruction Formulation

The PDT also formulated the only other possible related measure would be to divert water around the levee system, which based on preliminary cost estimates, was ruled out very early, or system functionality which included reconstruction measures of the system. The PDT addressed the reconstruction decision flowchart questions and found the following results:

1. Is the sponsor seeking a higher level of protection (i.e., raise the levee)?
    - The PDT evaluated whether a 1/500 ACE level of protection for the overtopping risk. This would be addressed with this authority (WIIN Act of 2016) & cost sharing (WRDA 86 and Bipartisan Act of 2018). The PDT assessed the remaining needs due to breach prior to overtopping and moved to the next decision question.
2. Is there a design or construction deficiency?
    - The PDT evaluated and determined that there were no design or construction deficiency. The PDT assessed the remaining needs due to risk of failure and moved to the next decision question.
3. Is there maintenance concerns?
    - The PDT evaluated and determined that the Levee District has continued to be in good standing and has remained eligible for rehabilitation assistance under Public Law (P.L.) 84-99 under the System Wide Improvement Framework (SWIF) Program. In addition, many components within the deficient O&M items have become functionally obsolete and the replacement parts have been unavailable and no longer manufactured. Therefore, the PDT accessed the remaining needs due to risk of failure and moved to the next question.
4. Is there a change in condition?
    - The PDT assessed and found that there were no changes in conditions; therefore, the PDT evaluated the remaining needs due to risk of failure and moved to the next question.

5. Is there long-term degradation and/or exceeded service life?
    - The PDT evaluated remaining issues with system functionality, which were not associated with a PFM or life safety risk using current design and safety for pump stations, Charles Page Blvd Floodway Structure and Levee B tieback.

These reconstruction elements (Floodway Structure, Levee B tieback, and pump stations) are covered under this this authorization (WIIN Act of 2016) and would be cost shared with the non-Federal sponsor on a 65 percent Federal and 35 percent non-Federal basis, with the option of amortizing the 35 percent non-Federal share over 30 years (WRDA 86 and Bipartisan Act of 2018). Each of these reconstruction elements are described below.

Floodway Structure. Constructing a robust filter is recommended at the structure. Seepage issues arose during the May 2019 flood event, which were not identified as the primary risk driving failure modes during the 2016 SQRA. The culvert joints that posed an issue during the 1986 were recently sealed and performed well during the flood event. No seepage issues were noted or observed. The leaking joints provided pressure relief; however, with those locations now sealed and mostly watertight, the seepage exited in different locations. The pressure (gradient) was sufficient to initiate and continue the transport of material, thus creating the voids along the structure walls. A filler (mastic) is located between each wall panel but it does not fill the gap completely. It appears that a non-shrink type filler was not utilized, thus allowing water to easily penetrate these locations. Considering the issues above, the team addressed this structure under reconstruction. The estimated cost for reconstruction of the floodway structure is $1.2M.

Levee B Tieback. The tieback along Levee B was overtopped in 1984 during a localized flood event. Internal erosion combined with overland flow contributed to excessive erosion of the levee embankment. Constructing 2 detention ponds at the upper end of the tieback along with providing a 2-stage filter on the landside slope is recommended to address these known issues. The detention ponds would knock the peak off the inflow hydrograph, thus reducing the total height of loading on the levee with the additional storage volume. Constructing the 2-stage filter eliminates the potential for levee material to be transported and removed from within the embankment during these loading events. Considering the issues above, the team addressed the tieback associated with the floodway structure above under reconstruction. The estimated cost for reconstruction of Levee B tieback associated with the floodway structure is $7.9M.

Pump Stations. All seven pump stations are recommended for reconstruction. Each pump and motor are from original construction and have exceeded their intended useful design life. The work includes replacing each pump within each pump station. The total number of pumps varies from two to five within each station. All motors and electrical components will also be replaced. For more detail on each pump station, see Engineering Appendix A, Section 5. Considering these elements are instrumental in system functionality and effectiveness, the team addressed these items under reconstruction. The estimated cost for reconstruction of the pump stations is $9.8M.

3.5 Management Measures & Screening of Measures

Section 3.5 assesses preliminary measures and alternatives based on their ability to reduce flood and life safety risks.

3.5.1 Management Measures and Screening of Measures

A management measure is a structural or non-structural feature for a specific geographic site that addresses one or more planning objectives. Measures here were formulated based on potential failure modes (PFMs) from the SQRAs; lessons learned from the May 2019 flood event; and a system functionality analysis.

The PDT initially evaluated and formulated measures for all PFMs that plotted on or above the tolerable risk guideline (TRG) (as discussed in Chapter 1, Section 1.7) from the 2016 and 2017 SQRA.

See Table 3-1 below. (For more information and a list of all the PFMs, See the SQRA Summary Appendix D.)

Table 3-1: Structural and Non-structural Measures

PFM	Description	Measure	Carried Forward or Screened	Rationale
STRUCTURAL MEASURES				
Levee A				
15	Floodway Floatation - Box Culvert - leaky joints - 1/230 ACE – EL 650 feet (Approx. 307K CFS)	Full Cutoff - (North & South)	Carried Forward	
		Seal Joints	Carried Forward	
		Enlarge Culvert	Carried Forward	
		Construct New Bridge	Screened	This measure was screened for high cost.
35	CLE along Embankment Crack	Downstream Berm	Carried Forward	
		Cutoff Wall	Carried Forward	
		Filter Exits – toe drain	Carried Forward	
36	Slope Instability due to excessive uplift pressures	Cutoff Wall	Carried Forward	
		Landside Berm	Carried Forward	
		Relief Wells	Screened	This measure was screened due to complications with O&M and replacement of a measure (toe drain) which is a measure that has a comparable cost and performance. Sponsor indicates that relief wells are often damaged during mowing and can become problematic and an unnecessary cost. The team carried forward and evaluated toe drain measure.
Levee B				
1	Overtopping with Breach of Mainstem Levee Embankment	Permanently Raise Levee	Carried Forward	
		Armor DS Slope	Carried Forward	

PFM	Description	Measure	Carried Forward or Screened	Rationale
1T	Overtopping of Tieback Levee Embankment	Permanently Raise Levee	Screened	This measure was screened for high-cost and transfer of risk downstream.
		Urban Detention Ponds	Carried Forward	
		Mod of Outlet Works	Carried Forward	
34	BEP through Mainstem Levee Embankment	Filter Berm	Carried Forward	
		Cutoff Wall	Carried Forward	
		Face Riverside w/ Impervious Blanket	Carried Forward	
34T	BEP through Tieback Levee Embankment	Filter	Carried Forward	
		Cutoff Wall	Carried Forward	
		Face Riverside w/ Impervious Blanket	Carried Forward	
35	CLE along Embankment Crack	Downstream Berm	Carried Forward	
		Cutoff Wall	Carried Forward	
		Relief Wells	Screened	Same as above with Levee A PFM 36
		Filter	Carried Forward	
36	Slope Instability due to Excessive Uplift Pressures	Landside Berm	Carried Forward	
		Relief Wells	Screened	Same as above with Levee A PFM 36
		Cutoff Wall	Carried Forward	
37	BEP through Mainstem Levee Foundation -	Landslide Berm	Carried Forward	
		Cutoff Wall (Slurry)	Carried Forward	

PFM	Description	Measure	Carried Forward or Screened	Rationale
	Real Estate at P.S #4 – 15 feet	Relief Wells - at Toe	Screened	Same as above with Levee A PFM 36
Levee C				
1	Overtopping with Breach of levee Embankments	Permanently Raise Levee (Earth fill of Flood wall)	Carried Forward	
		Armor Slope	Carried Forward	
24	Misoperation of sandbag closure at SW Blvd	Raise road 2” to 2 ½”	Screened	This measure was screened for high cost measure to address misoperation of sandbag closure.
		Flood Wall structure with flap gate	Carried Forward	
1Tr	Overtopping with breach due to heavy loading	Raise levee on North Side of BBQ	Screened	This measure was screened for high cost measure and no life risk associated with overtopping within Levee C during second iteration.
		Flood wall structure with flap gate	Carried Forward	
36	Slope Instability due to excessive uplift pressures at landside toe	Downstream Berm	Carried Forward	
		Relief Wells	Screened	Same as above with Levee A PFM 36
		Cutoff Wall	Carried Forward	
Levee A, B and C				
27	Concentrated Leak Erosion (CLE) along Conduit	Filter Exit (S)	Carried Forward	
		Cutoff Wall	Carried Forward	
28	CLE/BEP into Conduit	Replace Conduit (S)	Carried Forward	
		Abandon Conduit (S)	Carried Forward	

PFM	Description	Measure	Carried Forward or Screened	Rationale
Approximately 180 penetrations in Levees A & B; 160 penetrations in Levee C				
N/A	Pump Stations	Update/Reconstruct Pump Stations (S) – Reconstruction of the system would include an evaluation of the pump stations for effectiveness of the system as originally designed and updated to today's standards.	Carried Forward	
NON-STRUCTURAL MEASURES				
		Buyout and Relocation (NS)	Carried Forward	
		Flood Proofing (NS)	Screened	Not practical due to amount of structures impacted. Does not address life safety and evacuation concerns
		Raise/elevate Structures (NS)	Screened	Not practical due to a high number of structures that were impacted and up to 10 to 12 feet of elevation due to depth of inundation. For example, to raise a 1,500 square foot slab on grade structure 12 feet would cost about $88,000. In addition, most residential structures are over 70 years old and would pose high structural risk for damage during elevation. Due to the depth of flooding, structural integrity of the aging residential structures and the cost of elevating the structures, this measure was screened from further consideration.
		Evacuation Plan/Flood Warning Systems	Carried Forward	
		Easement/Pay Landowners for Water Retention	Carried Forward	

Structural measures carried forward for evaluation included:

- **Filtered berms** - Mounds of soil such as sand, gravel, or clay constructed adjoining and parallel to the landside toe of the levee designed to relieve water pressure and prevent soil particle from moving through or beneath the levee.
- **Toe drains** - A perforated pipe at the toe of the levee used with a horizontal filter drain to collect seepage from the levee and foundation to prevent movement of soil.
- **Cutoff walls** - A barrier constructed through the levee and levee foundation with very low permeability such as concrete to limit the movement of ground water through or under the levee.
- **Flood wall** - A vertical artificial barrier typically made of reinforced concrete to contain river water.
- **Impervious blanket** – A low permeability layer designed to limit movement of water through the levee and levee foundation.
- **Pump station** - Pumps and other equipment to move water from local runoff out of the levee when the river is at a higher elevation.

Non-Structural measures carried forward included:

- **Buyout and Relocation** - Consists of buying residential structures and land. Structures are either demolished or sold and relocated. Remaining land is often rezoned as open space for recreation or ecosystem restoration.
- **Flood Emergency Preparedness Plans (FEPPs)** - FEPP outline a community's response to flooding including factors such as: location of evacuation centers, primary evacuation routes, and post flood recovery processes.

3.6 Formulation of Initial Array of Alternatives

An initial array of flood risk management alternative plans were developed, evaluated and compared to identify a plan that reasonably maximizes reduction in flood and life safety risks.

The PDT then merged these measures into combinations using engineering judgment that addressed each PFM for the levee (i.e., Levee A, B, C and/or all the levee system) to formulate specific alternatives (Table 3-2). Table 3-3 illustrates measures that the team combined to formulate alternative. For more information about PFMs, see Engineering Appendix A and SQRA Summary Appendix D.

Table 3-2: Measures Developed into Alternatives

Levee A											
		Alternative 1 - Filtered Exits[1]					Alternative 2 - Cutoff Walls[1]				Alternative 3 – Full Cutoff Wall	
PFM	Measure	Alt 1A	Alt 1B	Alt 1C	Alt 1D	Alt 1E	Alt 2A	Alt 2B	Alt 2C	Alt 2D	Alt 3A	Alt 3B
15	Anchor Culverts	X	X	X	X	X	X	X	X	X	X	X
	Seal Joints	X	X	X	X	X						
	Cutoff Wall						X	X	X	X	X	X
35	Cutoff Wall						X	X	X	X	X	X
	Filter exit - toe drain	X	X	X	X	X						

[1] - Scaling within Alternatives 1 and 2 include:

1. “A” scaling combined all measures that addressed breach prior to overtopping with filtered berm and toe drains for the entire levee system (Levee A, B and C) and all failure modes (including overtopping and breach prior to overtopping);
2. “B” Scaling included Levee A and B only (Not addressing Levee C) and all failure modes (including overtopping and breach prior to overtopping);
3. “C” Scaling included the entire levee system (Levee A, B and C) but did not address overtopping;
4. “D” Scaling included Levee A and B only (Not addressing Levee C or overtopping); and
5. “E” Scaling was added after the 2019 SQRA and flood event and included Levee A and B only (Not addressing Levee C) and addressed overtopping with armoring the location to lower the risk of failure but not raising the levee.

	Landside Berm	X	X	X	X	X						
36	Cutoff Wall						X	X	X	X	X	X
	Landside Berm	X	X	X	X	X	X	X	X	X		
Levee A Tieback												
		Alternative 1 - Filtered Exits					**Alternative 2 - Cutoff Walls**				**Alternative 3 – Full Cutoff Wall**	
PFM	**Measure**	**Alt 1A**	**Alt 1B**	**Alt 1C**	**Alt 1D**	**Alt 1E**	**Alt 2A**	**Alt 2B**	**Alt 2C**	**Alt 2D**	**Alt 3A**	**Alt 3B**
N/A	Detention Ponds										X	
N/A	Cutoff Wall										X	
Levee B												
		Alternative 1 - Filtered Exits					**Alternative 2 - Cutoff Walls**				**Alternative 3**	
PFM	**Measure**	**Alt 1A**	**Alt 1B**	**Alt 1C**	**Alt 1D**	**Alt 1E**	**Alt 2A**	**Alt 2B**	**Alt 2C**	**Alt 2D**	**Alt 3A**	**Alt 3B**
1	Raise Levee	X	X				X	X			X	
	Armor Landside Slope					X	X	X				X
34	Filter	X	X	X	X	X						
	Cutoff Wall						X	X	X	X	X	X
	Cutoff Wall						X	X	X	X	X	X
	Landside Berm											
36	Landside Berm	X	X	X	X	X						
	Relief Wells or Toe Drain	X	X	X	X	X						

	Cutoff Wall						X	X	X	X	X	X
37	Landside Berm	X	X	X	X	X						
	Cutoff Wall						X	X	X	X	X	X
Levee B Tieback												
		Alternative 1 - Filtered Exits					**Alternative 2 - Cutoff Walls**				**Alternative 3**	
PFM	**Measure**	**Alt 1A**	**Alt 1B**	**Alt 1C**	**Alt 1D**	**Alt 1E**	**Alt 2A**	**Alt 2B**	**Alt 2C**	**Alt 2D**	**Alt 3A**	**Alt 3B**
1T	Detention Ponds	X	X			X					X	X
	Raise Levee						X	X				
34T	Filter	X	X	X	X	X						
	Cutoff Wall						X	X	X	X	X	X
	Impervious Blanket (Riverside)											
Levee C												
		Alternative 1 - Filtered Exits					**Alternative 2 - Cutoff Walls**				**Alternative 3**	
PFM	**Measure**	**Alt 1A**	**Alt 1B**	**Alt 1C**	**Alt 1D**	**Alt 1E**	**Alt 2A**	**Alt 2B**	**Alt 2C**	**Alt 2D**	**Alt 3A**	**Alt 3B**
1	Raise Levee	X									X	X
	Armor Landside Slope						X					
1Tr	Floodwall Structure											
	Raise Road/Levee											
24	Floodwall Structure											

	Raise Road/Levee											
36	Landside Berm	X		X								
	Filter	X		X								
	Cutoff Wall						X		X		X	X
All Levees												
		Alternative 1 - Filtered Exits					**Alternative 2 - Cutoff Walls**				**Alternative 3**	
PFM	**Measure**	**Alt 1A**	**Alt 1B**	**Alt 1C**	**Alt 1D**	**Alt 1E**	**Alt 2A**	**Alt 2B**	**Alt 2C**	**Alt 2D**	**Alt 3A**	**Alt 3B**
27	Filter Exit	X	X	X	X	X						
	Cutoff Wall						X	X	X	X	X	X
28	Replace Conduit	X	X	X	X	X	X	X	X	X	X	X
	Abandon Conduit	X	X	X	X	X					X	X
Alt 1B, 1D, 2B & 2D only address the penetrations at Levee A & B												

Table 3-3: Combined Measures into Array of Alternatives

	Alternative 1 – Filtered Berm with Toe Drain	Alternative 2- Filtered Berm and Cutoff Wall combination	Alternative 3 - Full Cutoff Wall
A – Entire system and all PFMs	Levee A - Anchor Culvert & Seal Joints Levee B - Berm/Filtered Exits & Raise Levee Levee B Tieback - Filter & Detention Pond Levee C - Berm/Filtered Exits, Raise Levee All Levees - Replace/Abandon Conduits & Filtered Exits	Levee A - Anchor Culvert & Seal Joints Levee B - Cutoff Wall, Raise Levee & Armor L/S Slope Levee B Tieback - Cutoff Wall & Raise Levee Levee C - Cutoff Wall & Armor Slope All Levees - Replace Conduits	Levee A - Cutoff Wall & Raise Levee Levee A Tieback - Cutoff Wall & Detention Pond Levee B - Cutoff Wall & Raise Levee Levee B Tieback - Cutoff Wall & Detention Pond Levee C - Cutoff Wall, Raise Levee All Levees – Replace/Abandon Conduits
B – All PFMs for Levee A and B only	Levee A - Anchor Culvert & Seal Joints Levee B - Berm/Filtered Exits & Raise Levee Replace/Abandon Conduits & Filtered Exits Levee B Tieback - Filter & Detention Pond Levee C – None	Levee A - Anchor Culvert & Seal Joints Levee B - Cutoff Wall, Raise Levee & Armor L/S Slope Levee B Tieback - Cutoff Wall & Raise Levee Levee C - None All Levees - Replace Conduits	Levee A - Cutoff Wall Levee A Tieback - Cutoff Wall & Detention Pond Levee B - Cutoff Wall Levee B Tieback - Cutoff Wall & Detention Pond Levee C - None All Levees – Replace/Abandon Conduits Reconstruction – Pump Stations #1-7
C – Entire System without overtopping	Levee A - Anchor Culvert & Seal Joints Levee B - Berm/Filtered Exits Levee B Tieback - Filter Levee C - Berm/Filtered Exits All Levees - Replace/Abandon Conduits & Filtered Exits	Levee A - Anchor Culvert & Seal Joints Levee B - Cutoff Wall Levee B Tieback - Cutoff Wall Levee C - Cutoff Wall All Levees - Replace Conduits	
D – Levee A and B only without overtopping	Levee A - Anchor Culvert & Seal Joints Levee B - Berm/Filtered Exits & Raise Levee Replace/Abandon Conduits & Filtered Exits Levee B Tieback - Filter Levee C – None	Levee A - Anchor Culvert & Seal Joints Levee B - Cutoff Wall Levee B Tieback - Cutoff Wall Levee C - None All Levees - Replace Conduits	

E – Levee A and B only without overtopping with system functionality reconstruction	Levee A – Berm/Filtered Exists with Toe Drain Levee B – Berm/Filtered Exists with Toe Drain Replace/Abandon existing conduits and Filtered Exists Floodway Structure – Berm/Filtered Exists with Toe Drain Levee B Tieback – Detention ponds Levee C – None Reconstruction – Pump Stations # 1-7		

ALTERNATIVE 1 – FILTERED BERM WITH TOE DRAIN

- **Alternative 1A** would address all potential failure modes for the system (A, B and C) primarily with filtered exits. Conduits would be abandoned and/or replaced and filtered exits constructed.

    - Levee A: Construct full cutoff walls at Charles Page Blvd (North and South) for approximately 600 feet and seal joints where needed and full cutoff wall at the Superfund Site for a combined total of approximately 15,000 feet.
    - Levee B: Permanently raise Levee B back to original design flow at pump station 5 for about 3,000 feet; construct a stability berm with a filtered exit and relief wells at pump station 4; and a detention pond(s) on approximately 30 acres behind Levee B and filter along the tieback.
    - Levee C: Permanently raise Levee C back to original design flow at I-244 Corridor for roughly 1,000 feet; construct a landside berm with relief wells for 6,800 feet; and construct a flood wall structure with flap gate.
    - Non-Structural measures include: Update the City of Tulsa Hazard Mitigation Plan; update Temporary Evacuation Plan; Update Warning System; residential buy-out; and raise structures.

- **Alternative 1B** would address all PFMs for Levee A and B, primarily with filtered exits. Throughout Levee A and B, conduits would be abandoned or replaced and filtered exits constructed. This is the same as Alternative 1A, but without Levee C.
- **Alternative 1C** would address many PFMs (except no overtopping failure modes) for the entire system (A, B and C) primarily with filtered exits. Throughout the entire levee system (A, B and C), conduits would be abandoned and/or replaced and filtered exits constructed. This the same as Alternative 1A but with no levee raise in Levee B or Levee C.
- **Alternative 1D** would address penetration failure modes (except no overtopping failure modes) for Levee A and B only, primarily with filtered exits. Throughout Levee A and B, conduits would be abandoned and/or replaced and filtered exits constructed (same as Alternative 1C but with no issues addressed within Levee C).
- **Alternative 1E** was recommended by the risk cadre during the 2019 SQRA and refined as the team formulated through the process to address seepage and erosion for Levee A and B. It would involve constructing a filtered berm with toe drain except for a cutoff wall to rock at the Superfund Site for 2,000 feet for Levee A. Alternative 1 E would also construct a robust filter at the Charles Page Floodway Structure. Other elements include armoring the landside slope at pump station 5 for 3,000 feet; constructing a detention pond for the 100-year storm above the Levee B tieback, and reconstructing pump stations 1 through 7. Levee A and B conduits deemed unnecessary would be abandoned and those required for continued operation of the system would be replaced.

ALTERNATIVE 2 – CUTOFF WALL AND FILTERED BERM WITH TOE DRAIN

- **Alternative 2A** would address all PFMs for the system primarily with cutoff walls. For levees A, B and C a cutoff wall would be constructed at each penetration for a total of about 6,800 feet and would replace approximately 90 conduits.

    - Levee A: Construct full cutoff walls at Charles Page Blvd (North and South) for 600 feet and seal joints where needed; full cutoff wall at the Superfund Site for 15,000 feet; and construct a detention pond for tieback.
    - Levee B: Permanently raise Levee B back to original design flow and armor landside slope at pump station 5 for 3,000 feet; construct a cutoff wall for 3,000 feet at pump station 4; and raise levee to original design flow and construct cutoff wall for 9,000 feet along the tieback.
    - Levee C: Armor landside slope at I-244 Corridor for 1,000 feet; construct a cutoff wall for 6,800 feet; and construct a flood wall structure with flap gate.
    - Non-Structural measures for Alternative 2 include updating Tulsa's Hazard Mitigation Plan; Evacuation Plan; Warning System; and a potential buy-out of homes.

- **Alternative 2B** would address all PFMs for Levee A and B, primarily with cutoff walls. Throughout Levee A and B, a cutoff wall would be constructed at each penetration for 3,600 total feet and replace 65 conduits. Remaining areas in Levee A and B would be addressed with filtered berm with toe drains. This alternative is the same as Alternative 2A but does not include Levee C.
- **Alternative 2C** would address penetration failure modes (no overtopping failure modes) for the entire levee system primarily with cutoff walls. Throughout the entire levee system (A, B and C), cutoff walls would be constructed at each penetration and conduits replace. This is the same as Alternative 2A with no levee raises in B or C.
- **Alternative 2D** would address penetration failure modes (no overtopping failure modes) for Levee A and B. This is the same as Alternative 2C but without Levee C.

ALTERNATIVE 3 – FULL CUTOFF WALL

- **Alternative 3A** would address potential failure modes for the entire system primarily with a permanent levee raise to 1/500 ACE and permanent levee raise of 1/100 ACE for tiebacks. A cutoff wall would be constructed along the entire levee system (A, B and C) (20 miles) and 90 conduits would be replaced. Non-structural measures would include updating Tulsa's Hazard Mitigation Plan; Evacuation Plan; Update Warning System; and potential buyout plans.

- **Alternative 3B** is the same as Alternative 3A, except that it would not raise the main-stem or tie backs in the system and would not address issues for Levee C. This alternative would also construct a robust filter at Charles Page Floodway Structure, and buyout properties in the landside toe where required and other properties as needed. It would install armor landside slope at pump station for 3,000 feet; and construct a detention pond for the 100-year storm above Levee B tieback. Levee A and B conduits deemed unnecessary would be abandoned and all required for continued operation of the system would be replaced. Pump station 1 through 7 would also be reconstructed.

ALTERNATIVE 4: DIVERSION OF THE WATER AROUND TULSA

Alternative 4 would construct gravity flow pipelines to reduce flow around Tulsa.

ALTERNATIVE 5: NON-STRUCTURAL ALTERNATIVE

Alternative 5 would buy out all residential structures behind Levees A and B and relocate.

ALTERNATIVE 6: NO ACTION ALTERNATIVE

The No action alternative assumes no federal involvement; however, this does not preclude locally sponsored activities without federal participation. In addition, the No Action scenario assumes that existing levee systems would be maintained and residual flood risks would remain.

3.7 SECOND ITERATION OF FORMULATION OF ALTERNATIVES

Subsequently, a March 2019 SQRA was performed utilizing Tulsa County's updated warning and evacuation system and the PDT's updated warning times. Many of the PFMs from the 2016 and 2017 SQRAs plotted below the TRG line in the 2019 SQRA.

Also during formulation, Tulsa County experienced a major flood event in May 2019. These events altered the evaluation. The PDT performed another iteration based on the updated results of the March 2019 SQRA and the May 2019 flood event.

Error! Reference source not found.5 summarizes failure modes addressed in this study after the 2019 SQRA and flood event. For a list of all PFMs and details about the SQRA see the Engineering Appendix A and SQRA Summary Appendix D.

Table 3-5: 2019 Potential Failure Modes (PFMs)

Mode	Description
1	Overtopping of Mainstem Levee Embankment
15	Floodway Structure
27	Concentrated Leak Erosion (CLE) Along a Conduit
28	Internal Erosion into Conduit
34	Backward Erosion Piping (BEP) through Mainstem Levee Embankment
35	CLE along Sloped Construction Interface
36	Slope instability due to excessive uplift pressures
37	BEP through Mainstem Levee Foundation

As indicated above, PFM 1 is associated with overtopping, while all other PFMs are associated with some type of erosion or seepage issue.

In addition, the 2019 SQRA evaluated no life safety risk for Levee C and Levee B tieback; therefore, the PDT screened Levee C and Levee B tieback from further evaluation or formulation in the study.

The PDT discussed the updated PFMs and the erosion and seepage experienced during the May 2019 flood event and evaluated structural and non-structural measures for the PFMs from the SQRAs. Other measures for system effectiveness were evaluated. Different components of the levee system had become obsolete and the PDT evaluated technology that is being reconstructed for system functionality and efficiency.

The May 2019 flood event provided actual evidence of potential issues and the locations of these issues. The 2016 SQRA provided locations deemed most critical based on geologic logs, past events and engineering judgment. These areas did not correspond to the locations where issues arose during the May 2019 flood event. An additional location of erosion was at the Charles Page floodway structure. Significant erosion issues were observed compared to potential uplift issues identified in the original 2016 and 2017 SQRA. The high water caused erosion under and along the Floodway Structure walls creating significant voids. Sandbag ring dikes were filled with sand, then overlain with gravel along the walls to prevent further erosion.

The most cost effective measure for addressing the Floodway Structure was a robust filter with toe drain and to remove some of the load from the tributaries. Therefore, the PDT reinstated and evaluated the Levee B tiebacks for reconstruction of the system. The PDT analyzed that addressing the Levee B tieback with two detention ponds (to capture approximately 1/100 ACE) lessened the amount of tributary flooding coming into the floodway structure. Therefore, PFM 15, 1T and 34T were carried forward as reconstruction measures to address system functionality.

3.8 EVALUATION OF INITIAL ARRAY OF ALTERNATIVES

The study team gathered existing information on the levee system, information from the sponsor, stakeholders, and state and Federal agencies. Each alternative was formulated under the umbrella of the four planning criteria (completeness, effectiveness, efficiency, and acceptability) described in the *Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, dated March 1983 (P&G) as well as directives of Executive Order (EO) 11988.

3.9 Transfer of Risk

Originally, many alternatives initially included an increase in the level of protection along the main stem levee to a 0.2 percent ACE (1/500 ACE) flood along the Arkansas River. This level of protection corresponded to a discharge of 490,000 cubic feet per second (cfs). A scenario was developed in the HEC-RAS model that took the October 1986 release hydrograph from Keystone Dam and scaled all of the ordinates so that the peak discharge matched the 0.2 percent ACE flood. The geometry of the HEC-RAS model was modified so that the "bump outs" constructed within the Arkansas River as part of the development of The Gathering Place were accounted for. The Gathering Place is a public open space centered on the east bank of the Arkansas River along Riverside Drive approximately two miles south of downtown Tulsa and adjacent to the Maple Ridge historic district, an upscale residential area. This public-private partnership covers approximately 100 acres of land and cost about $465 million to construct.

The HEC-RAS model was set up with two different geometries for the 0.2 percent ACE flood scenario. The original geometry file included Levees A, B, and C with existing crest profiles. As they currently exist, the levees offer a 0.4 percent ACE minimum level of protection (Levee B will overtop with an estimated flow of 360,000 cfs). A second geometry file was then created with all levee crests raised so that they contained the 0.2 percent ACE flood. The 0.2 percent ACE scenario was then run with both of the geometry files so that the incremental differences in the water surface profiles along the Arkansas River could be determined.

Once the HEC-RAS modeling was completed for the 0.2 percent ACE, it was obvious that any increase in the crest heights of Levees A, B and C would increase the water surface profiles in the vicinity of the TWT Levee system. This effect was most pronounced immediately upstream

and across from Levee A (on the right bank of the Arkansas River), and also across from Levee C on the left bank of the Arkansas River. In both areas, the increased depths as a result of the implementation of the 0.2 percent ACE would affect residential structures. The impacts opposite Levee A on the right bank of the Arkansas River would increase 0.2 percent ACE depths in the Town and Country subdivision in unincorporated Tulsa County by 2-5 feet.

The impacts opposite Levee C on the left bank of the Arkansas River would increase 0.2 percent ACE depths in low-lying areas within the Maple Ridge historic district adjacent to the Gathering Place. In this area, including the Gathering Place, flood inundation depths would increase by 2-5 feet over existing 0.2 percent ACE conditions. This effect was less pronounced in the HEC-RAS model downstream from the Midland Valley Trail / River Parks Pedestrian Bridge, located along Riverside Drive at 28th Street in Tulsa.

Since the 0.2 percent ACE increased flood inundation depths both opposite Levee A on the right bank of the Arkansas River and opposite Levee C on the left bank of the Arkansas River, it represented a transfer of risk. This transfer of risk was not trivial (with increases in flood inundation depths of 2-5 feet), and it affects both residential areas and public use areas with significant levels of financial investment. Therefore, the transfer of risk posed by the adoption of the 0.2 percent ACE was deemed unacceptable by the PDT, and after consultation with the local sponsor, raising the levee was screened from further analysis.

ER 1165-2-26 provides general guidance and policy for USACE implementation of EO 11988 for all civil works projects. Paragraph 7 of the regulations states:

“It is the policy of the Corps of Engineers to formulate projects which, to the extent possible, avoid or minimize adverse impacts associated with use of the base floodplain and avoid inducing development in the base floodplain unless there is no practicable alternative. The decision on whether a practicable alternative exists will be based on weighing the advantages and disadvantages of floodplain sites and non-floodplain sites. Factors to be taken into consideration include, but are not limited to… the functional need for locating the development in the floodplain. The test of practicability will apply to both the proposed USACE action and to any induced development likely to be caused by the action.”

Based on directives of EO 11988, Alternative 1 (Alternative permutations A, B and D), Alternative 2 (Alternative permutations A and B), and Alternative 3A were screened and removed from further consideration due to induced damages and transference of flood risk downstream (See Hydrology and Hydraulics Appendix B for additional detail regarding induced damages and risk transfer).

Remaining alternatives were evaluated based on P&G criteria and due to high construction costs, environmental impacts and other social effects, Alternative 2 (C and D) and Alternative 4 dropped from further consideration (Table 3-4).

Alternative 1C was screened for constructability concerns and incompleteness. Alternatives that carried forward for further evaluation included alternatives 1E, 3B 5, and the No Action plan.

Table 3-4: Alternative Evaluation

Alternative	Scaling	Cost * (L/M/H)	Risk Reduction (Y/N)	Transfer Risk (Y/N)	Environ Impacts (L/M/H)	Constructability/ Implementability concerns (L/M/H)	Rationale
Alternative 1 – Filtered Berm w/ Toe Drains	A	M	Y	Y	H	H	Screened for transfer risk and high environmental impacts because construction extends outside the existing footprint
	B	M	Y	Y	H	H	Screened for transfer risk and high environmental impacts because construction extends outside the existing footprint
	C	M	Y	N	H	H	Screened for Levee C – no life safety risk
	D	M	Y	Y	H	H	Screened for transfer risk and high environmental impacts because construction extend outside the existing footprint
	E	M	Y	N	L	L	Alternative 1E – Carried Forward for further evaluation

Alternative	Scaling	Cost * (L/M/H)	Risk Reduction (Y/N)	Transfer Risk (Y/N)	Environ Impacts (L/M/H)	Constructability/ Implementability concerns (L/M/H)	Rationale
Alternative 2 – Cutoff Wall and Filter Berm	A	M	Y	N	H	M	Screened for transfer risk and high environmental impacts because construction extends outside the existing footprint and constructability concerns
	B	M	Y	Y	H	M	Screened for transfer risk and high environmental impacts because construction extend outside the existing footprint
	C	M	Y	N	M	M	Screened for Levee C – no life safety risk
	D	M	Y	Y	H	M	Screened for transfer risk and high environmental impacts because construction extends outside the existing footprint and constructability concerns
Alternative 3 – Full Cutoff Wall	A	H	Y	Y	H	H	Screened for transfer risk and high environmental impacts because construction extends outside the existing footprint and constructability concerns with sealing numerous conduits going through the wall

Alternative	Scaling	Cost * (L/M/H)	Risk Reduction (Y/N)	Transfer Risk (Y/N)	Environ Impacts (L/M/H)	Constructability/ Implementability concerns (L/M/H)	Rationale
	B	H	Y	N	H	H	Alternative 3B - Carried Forward for further evaluation.
Alternative 4 – Divert Water around Tulsa		H	N	Y	H	H	Screened for High Cost, environmental and other social effects, transfer risk.
Alternative 5 – Residential Buyout behind Levee A and Levee B		H	Y	N	L	L	Carried forward for further evaluation.
Alternative 6 – No Action		L	N	N	L	N/A	Carried Forward as baseline

**Cost – Low ($0 to $100M); Moderate ($101M to $200M); High ($201M +)*

3.10 Final Array of Alternatives

After evaluating and screening the initial array, the study team evaluated the final array of alternatives.

Alternative 1E (Filter Berm with Toe Drain)

Alternative 1E would address seepage and erosion with the following:

1) A filtered material berm with toe drain along the entire length of Levee A and Levee B and a robust filter at the Charles Page Blvd. Floodway Structure.
2) A cutoff wall to rock at the Superfund Site at Levee A for 2,000 feet with construction easements as needed (see Real Estate Appendix F for details).
3) 3,000 feet of armored landside slope at pump station 5
4) Two detention ponds above Levee B tieback sized to capture 100-year flood volumes.
5) Levee A and Levee B conduits that are deemed unnecessary will be abandoned and all others required for continued operation of the system will be replaced. Reconstruction of Pump Station Nos. 1 through 7.

Alternative 3B (Full Cutoff Wall)

Alternative 3B would address all potential failure modes for Levee A and Levee B with the following:

1) 13 miles of cutoff wall
2) Replacement of 90 conduits (all others would be abandoned).
3) 2,000 feet of cutoff wall to rock at the Superfund Site at Levee A.
4) Buy out of properties within 50 feet of landside toe where required and other properties as needed.
5) 3,000 feet of armoring for the landside slope at pump station 5.
6) Two detention ponds above the Levee B tieback sized to capture 100-year flood volumes.
7) Reconstruction of pump stations 1 through 7.
8) Removal of Levee A tieback west of Hwy 412 and decommission tieback.

Alternative 5 (Buyout Residential properties behind Levee A and B)

The PDT evaluated different grouping(s) and locations of various buyout options; however, potential life loss was spread throughout Levee A and Levee B as inundation covers most land behind the levee, particularly for low frequency events, and there are no areas that had significant clusters of life loss that could be targeted. In other words, the flooding from either a 200 or 500 year event basically inundates the entire area.

Thus, based on these facts, the PDT concluded that the entire Levee A and Levee B residential population would have to relocate in order to eliminate risks to life safety. With respect to economics, it's important to note that residential property value (content and structure) accounts for only about 30 percent of total property value behind Levee B; and thus, the BCR referenced in the comment would be significantly lower assuming the very conservation estimate of 200M for buyout costs, and drastically lower if buyout costs were at the higher range of 400M.

Lastly, there would be significant sociopolitical ramifications of a buyout. Most of the affected homes are in the incorporated area of Sand Springs that has (based on the Census Bureau's 2017 American Community Survey) 7,702 households, and a total buyout would remove 2,051 homes from the community, which would have major consequences to the local government and businesses in terms of finances. Local tax revenues would fall considerably as would local business revenues, all of which would have reverberations throughout the local economy, and it is unlikely that many residents could remain the same general area given that housing costs outside of the impact area in Sand Springs and Tulsa are much higher.

EO 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations*, tasks “each federal agency [to] make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionally high adverse human health and environmental effects of its programs, policies, and activities on minority populations and low-income populations.” EO12898, dated February 11, 1994, aims to:

- Focus the attention of federal agencies on the environmental and human health conditions in minority communities and low-income communities with the goal of achieving environmental justice;
- Foster non-discrimination in federal programs that substantially affect human health or the environment; and
- Give minority communities and low-income communities’ greater opportunities for public participation in, and access to public information on, matters relating to human health and the environment.

A census block group is considered an environmental justice low-income population area is 20 percent or more of the households in a block group have incomes below the poverty line as specified by the U.S. Census Bureau. Based on Census data, about 22 percent of households

by Levee A live below the poverty line, and by Levee B slightly more than 19 percent. There are also numerous schools, daycares, churches, nursing homes and assisted living facilities and recreational areas (parks) within the study area. For more details on population and demographics, see Economic Appendix C.

Alternative 6 (No Action)

Alternative 6 assumes there will be ongoing and potential for local or state sponsored projects that could be undertaken without Federal participation. It is expected that current FRM structures would be maintained and residual risk of flood damages would remain. For example, The FWOP is the most likely condition expected to exist in the absence of a proposed water resource project, and it is the benchmark against which alternative plans are evaluated in the context of NEPA. Important assumptions regarding the FWOP condition include:

1) Residents behind the levee will continue to live in historically modified floodplain areas and be at risk of flooding.
2) A significant portion of the population behind the levees is made up of low income and elderly populations.
3) Historical events indicate that geotechnical failures in the study area are occurring and will occur in the future due to seepage.
4) Levee maintenance will continue under existing OMRR&R manuals and will be brought into compliance with those requirements using a System Wide Improvement Framework.
5) Any future development will occur in compliance with FEMA regulations, Oklahoma Senate Bill 5 and other local land-use planning rules and regulations.
6) The City of Tulsa and the County of Tulsa have updated their warning, and evacuation plans that contributed to decreased risks documented in the updated 2019 Keystone SQR. The No Action scenario assumes that all of these features and existing FRM management measures will remain in place in the future.

3.11 Consequence Modeling – Life Safety Risk

The team used the LifeSim model from the USACE Hydrologic Engineering Center (HEC) to estimate potential life loss from levee failure or overtopping. HEC-LifeSim for selected flood scenarios estimates flood causalities based on a structure inventory and population data in a specified area, and allows users to simulate evacuations and life hazard for people attempting to flee flooding by vehicle. LifeSim incorporates inputs developed economists and hydrologists such as a flood inundation data, emergency planning zones (i.e., impact areas) along with parameters such as flood warning times, and the public’s response to flood evacuation orders.

The program uses statistical sampling to compute thousands of iterations for flood events to obtain a stochastic range of possible life loss; and it distinguishes between nighttime and daytime population densities in area, which can significantly affect the estimated numbers of flood casualties.

Flood scenarios modeled are based on HEC-RAS inundation depth grids and one of two loading conditions at various levee control locations throughout the study area. The loading conditions were either:

1) Levee overtopping by 2 feet of water, or
2) Levee failure with surface water elevations at the top of levee (TOL).

Two-foot overtopping events assume an annual chance of exceedance (ACE) of 1 in 270 years along the Arkansas River and include a subset of scenarios where the levee fails or does not fail during overtopping; and top of levee failure scenarios assume an ACE of 1 in 230 years. For each scenario analyzed, a Monte Carlo uncertainty analysis was performed with uncertain variable inputs (warning issuance delay, warning diffusion, protective action initiation, warning time, and hazard communication delay) sampled from the distributions. Each scenario consisted of 1,000 iterations. The life safety risk for TOL fail and 2-foot overtopping scenarios ranged between 3 and 30.

3.12 Life Safety Reduction Evaluation of Final Array of Alternatives

Final Array of Alternatives were evaluated based on life safety benefits. The probability associated with inundation of investments in the floodplain are relatively low, the cost of each alternative exceeded the potential reduction in property damages. However, when evaluating each alternative based on life safety benefits several alternatives provided significant reduction in life safety risk.

The alternatives reduced risk associated with breach prior to overtopping failure modes. Life loss due to breach prior to overtopping drives the risk although the frequency of overtopping plots higher. Overtopping risk was addressed by providing an armored landside section along Levee B but does not lower the associated risk below TRG. The team looked into other measures to address overtopping but those transferred risk, as discussed in Section 3.9.

3.13 Economic Evaluation of Final Array of Alternatives

As required per USACE policy and the Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies (P&G), the study team evaluated study alternatives based on flood-related costs (i.e., damages avoided) that consist of structural damage to homes, businesses and other buildings and vehicles, and losses associated with damage to building contents such as furniture, electronics or industrial equipment. National economic development (NED) analysis was somewhat perfunctory given that the study team recognized early and agreed that formulation would focus on life safety rather the NED.

Methodology used meets criteria in Engineering Regulation ER 1105-2-100 (Planning Guidance Notebook). Models used are USACE certified tools developed by the Hydrologic Engineering Center (HEC) and consist of HEC-Flood Damage Analysis (HEC-FDA) software, and the recently developed hydrologic and economic data preprocessing module (HEC-GeoFDA). HEC-FDA is similar to HEC-LifeSim, but focuses on monetary damages rather than life loss. Cost and benefits are in FY2019 price levels and annualized using the 2019 federal discount rate for water resource projects of 2.875 percent.

Conclusions regarding justification based solely on economics are based on a comparison of annualized benefits to annualized costs via benefit to cost ratios (BCRs) where a value of 1.0 or more is economically justified, and the optimal plan or alternative from the perspective of National Economic Development is the one with greatest net economic benefits. As shown in Table 3-5 below, neither alternative (1B or 3B) generate positive net economic benefits in large part because most damages occur above the 200 ACE event level, and residential property values are relatively low (an average of about $33,000 per structure).

Expected annual damages for Alternative 5 were not estimated. Since Alternative 5 was added to the final array, and given that the total estimated costs ($200M to $400M that includes purchase of land and structures, demolition, and relocation) were higher than total costs of the recommended plan (Alternative 1B with total construction costs of $148 million and a BCR of 0.07).

This team has requested an exception from requirements to recommend a NED plan and seek approval of the tentatively selected plan based on life safety risks rather than monetized benefits. The P&G states, “A plan recommending Federal action is to be the alternative plan with the greatest net economic benefit consistent with protecting the Nation's environment (the NED plan), unless the Secretary of a department or head of an independent agency grants an exception to this rule.” Exceptions may be made when there are overriding reasons for recommending another plan, based on other Federal, State, local and international concerns

Table 3-5: National Economic Development Analysis[1]

Expected Annual Flood Damages and Risk Reduction Benefits			
Alternative	**Without Project**	**With Project**	**Damages Reduced (benefits)**
Alternative 1E (Filter Berm with Toe Drain)	$5,684,524	$5,198,062	$486,462
Alternative 3B (Full Cutoff Wall)	$5,684,524	$4,593,813	$1,090,711
Alternative 5 (Buyout and Relocation)2	$5,684,524	-	-
Annualized Alternative Costs *			
Alternative 1E (Filter Berm with Toe Drain)	$6,801,003		
Alternative 3B (Full Cutoff Wall)	$16,497,637		
Net Benefits and Benefit to Cost Ratio (BCR)			
	Benefit Cost Ratio	**Net Benefits**	
Alternative 1E (Filter Berm with Toe Drain)	0.07	($6,314,541)	
Alternative 3B (Full Cutoff Wall)	0.07	($15,406,926)	
*Includes construction costs (project first costs), interest during construction, and operation, maintenance, repair, rehabilitation, and replacement costs (OMRR&R). Assumes FY2019 price levels and interest rate of 2.875 percent.			

3.14 Evaluation of Final Array of Alternatives

Screening is an ongoing process of eliminating alternatives based on planning criteria. Criteria derive from a specific planning study, based on planning objectives, constraints, and problems and opportunities.

3.14.1 Evaluation of the four Planning Principles

Evaluation of the four planning principles were performed both quantitatively and/or qualitatively. The four planning principles are defined as:

- **Completeness** is the extent to which alternative plans provide and account for all necessary investments or other actions to ensure the realization of the planning objectives, including actions by other Federal and non-Federal entities. Part of the evaluation of completeness will include the contribution of the plan towards the resilience in the engineered infrastructure, as well as in the community, economy, and environment. Resilience is generally defined as the ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or anthropogenic, under all circumstances of use. Completeness also considers sustainability, which is an evaluation of whether plans include features and resources needed to meet study objectives in the study area beyond the period of analysis, and the impact of the proposed project.
- **Effectiveness** is the extent to which alternative plans contribute to achieve planning objectives. Effectiveness will also consider the resiliency of the plan, the contribution of redundant features to overall plan effectiveness, and the robustness of the plan. Redundancy is the duplication of critical components of a system with the intention of increasing reliability of the system, usually in the case of a backup or fail-safe. Robustness is the ability of a system to continue to operate as intended across a wide range of foreseeable operational conditions, with minimal damage, alteration, or loss of functionality, and to fail in a predictable way outside of that range.
- **Efficiency** is the extent to which an alternative plan is the most cost effective means of achieving the objectives. Efficiency also considers redundancy and robustness and should describe any potential trade-offs with economic efficiency.
- **Acceptability** is the extent to which alternative plans are acceptable in terms of the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with applicable laws, regulations and public policies.

Table 3-delineates how each alternative was evaluated using the four planning principles.

Table 3-10: Evaluation of Final Array of Alternatives with the Four Planning Principles

Alternative	Completeness	Effectiveness	Efficiency	Acceptability
1E – Filter Berm	**Complete plan** in that it includes all of the necessary investments to achieve the objectives and increases the resiliency of the levee. It is also **sustainable** if properly operated, maintained, repaired, rehabbed and replaced when necessary.	**Effective plan** in achieving the objective to reduce prior to overtopping life safety risk below the tolerable risk guideline. Also, effective in increasing the resiliency and robustness of the levee.	**Efficient plan** in reducing the life safety risk and is a **cost effective** plan.	**Acceptable plan** in terms of laws, regulations, and public policies. Also, anticipated to be publicly accepted from the general public, sponsor, affected communities, and governmental entities. This will be discussed further following the public review period.
3B – Cutoff Wall	**Complete plan** in that it includes all of the necessary investments to achieve the objectives and increases the resiliency of the levee. It is also sustainable if properly operated, maintained, repaired, rehabbed and replaced when necessary.	Effective plan in achieving the objective to reduce prior to overtopping life safety risk below the tolerable risk guideline. Also, effective in increasing the resiliency and robustness of the levee. However, there are **some significant constructability concerns** based on the number of penetrations through the cutoff wall that would have to be sealed. For this reason, risk and uncertainty associated with this plan are high.	An efficient plan in reducing the life safety risk. However, it is less cost effective at more than double the cost of 1E for one-half order of magnitude in reduction of risk. (See Table 3-9 below)	**Acceptable plan** in terms of laws, regulations, and public policies. Also, anticipated to be publicly accepted from the general public, sponsor, affected communities, and governmental entities. This will be discussed further following the public review period.
5 – Buy out	Complete plan for completely reducing the life safety risk However, it does **not** improve the resiliency of the levee.	Effective plan in achieving the objective to reduce prior to overtopping life safety risk below the tolerable risk guideline. However, it is not a cost effective plan and has significant social concerns.	Efficient plan in reducing the life safety risk, but is **not as cost effective as Alternative 1E.** (See Table 3-9 below)	This is **not anticipated to be a publicly accepted plan** from the general public, the sponsor, affected communities, and governmental entities. This will be discussed further following the public review period.
6 – No Action	**Not a complete** plan because it does not address any of the objectives and does not improve the resiliency of the levee.	**Not effective** because it does not achieve any of the objectives or increase the resiliency or robustness of the levee.	This plan is not efficient because it does not achieve any objectives of the study.	The No Action plan is unlikely to be acceptable to the public. However, this will be discussed further following the public review period.

3.14.2 Final Screening of Alternatives

The study team refined quantities and costs, performed various hydrologic and hydraulic modeling scenarios, and performed FDA and LifeSim modeling. Afterward, the team analyzed data with information regarding the May 2019 flood event, sponsor and stakeholders input, information from state and federal agencies, and used all of these data and information to conduct a final screening based on:

- Cost effectiveness,
- Risk reduction,
- Flood damages,
- Tolerable Risk Guideline 1,
- Tolerable Risk Guideline 4,
- Real estate impacts; and,
- Environmental screening criteria.

Table 3-6 summarizes the results of this evaluation. All three alternatives fully met TRGs 4; however, only Alternative 5 fully met TRG 1. Overtopping risk was addressed by providing an armored landside section along Levee B but does not lower the associated risk below TRG. The PDT evaluated what it would take to lower overtopping below TRG, but it significant and would not be justifiable.

Alternative 3 and 5 had high impacts to real estate, the environment, and cultural resources. High impacts to the environment and cultural resources were defined by the PDT as impacts that are significant enough to be challenging and costly to mitigate, and would warrant an Environmental Impact Statement (EIS).

Alternative 3 generated an additional one-half order of magnitude reduction in risk, but at a cost three times that of Alternative 1, which still partially met TRG 1 and fully met TRG 4. Therefore, the team recommended Alternative 1E as the tentatively selected plan.

Table 3-6: Evaluation of Final Array of Alternatives

Alternative	Total Cost [1]	Order of Magnitude Risk Reduction	TRG 1 (F/P/N) [2]	TRG 4 (F/P/N) [2]	Real Estate Impacts (L/M/H)	Environmental Impacts (L/M/H)
Alternative 1E (Filter Berm with Toe Drain)	$ 148M	2	P	F	Low to Medium	Low
Alternative 3B (Full Cutoff Wall)	$ 390M	2.5	P	F	High	High
Alternative 5 (Buyout)	$ 200M to $400M	3.0	F	F	High	High

1 - Cost is a Class 4 cost estimate. Construction cost only; does not include real estate; environmental mitigation; no utility relocation or removal; no S&A costs; etc.

2 - TRG 1 or 4 - Fully met (F); partially met (P); and Not met (N)

CHAPTER 4: RECOMMENDED PLAN

4.1 Tentatively selected plan (TSP)

Based on the comparison of these plans, the TSP is Alternative 1E (Filtered Berm with Toe Drains on Levee A and Levee B and reconstruction of Pump Station Nos. 1 through 7). This plan meets study objectives of reducing flood risk and flood damages, reducing flood risk to public health, safety and life, and minimizes residual flood risks to the extent justified. Alternative 1E is the Preferred Alternative based primarily on life safety. Environmental and cultural resources, as well as public input and costs, were also considered as part of the NEPA process. Structural features of Alternative 1E include (Figure 4-1):

- 13 miles of a filtered berm with toe drain,
- 3,000 feet of cut off wall in Levee A at the Superfund site;
- Filtered floodway structure,
- Two detention ponds at Levee B tieback;
- Impervious blanket armoring on landside at overtopping in Levee B; and,
- Reconstruction of pump station 1 through 7 for system-wide effectiveness and completeness.

Recommendations for addressing residual risk by the non-Federal sponsor include nonstructural features, such as comprehensive flood warning emergency evacuation planning and floodplain management. Specifics of these plans will be included in the language of the Project Partnership Agreement executed between the USACE and non-Federal sponsor.

Tulsa County is the anticipated funding source for the project implementation phases. Tulsa County will be required to obtain the required lands, easements, rights-of-way, relocations, and disposal areas (LERRD) in order to implement the project. This includes the lands required for the filtered berms, cutoff wall, impervious blankets, and detention ponds.

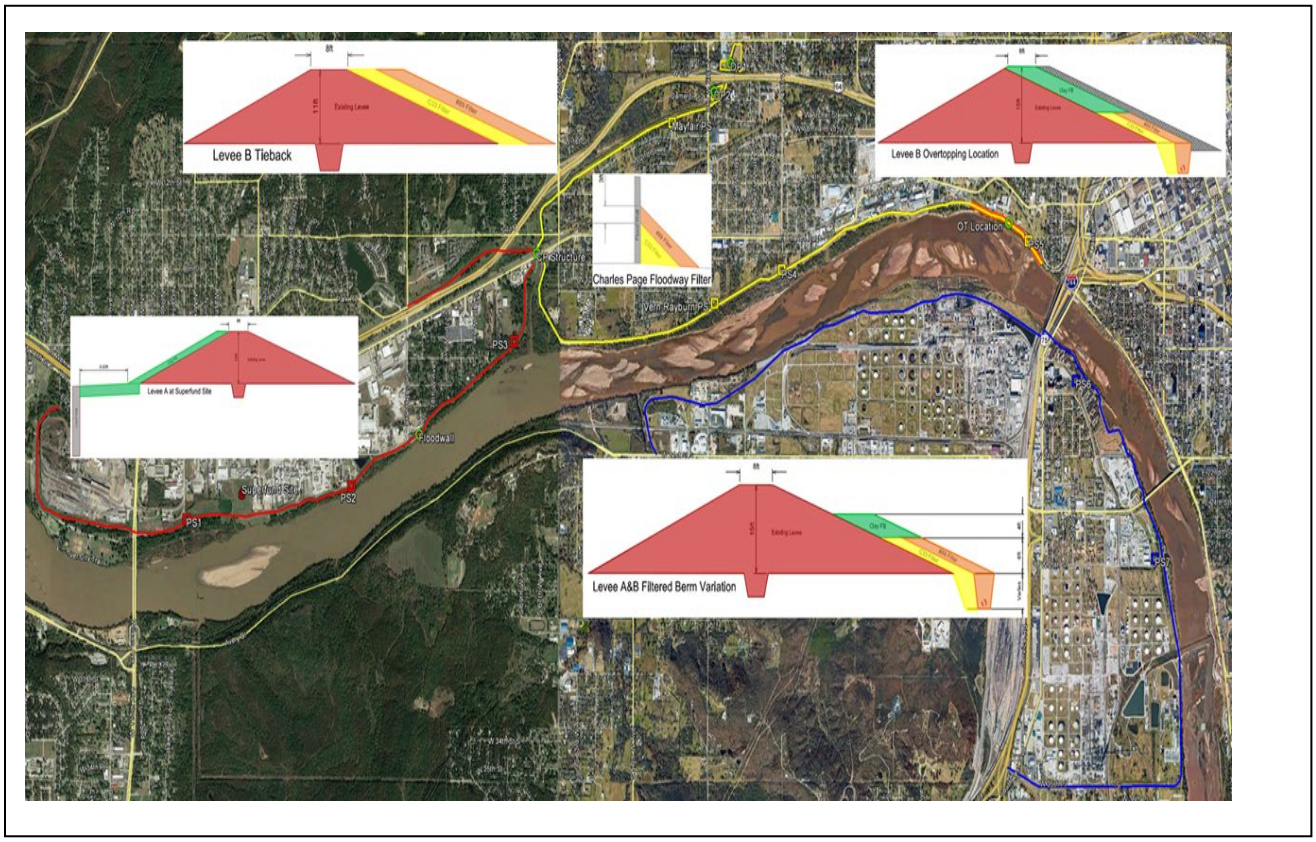

Figure 4-1: Schematic of the Tentatively Selected Plan Alternative 1 E

(Filtered Berm with Toe Drains on Levees A and B and Pump Reconstruction)

4.2 Residual Risk

Flood risk or residual risk is the risk of flooding in a leveed area that remains at any point in time after accounting for the flood risk reduction contributed by a levee system. The under and through seepage features that are part of the TSP will drive the annual probability of failure to a tolerable level below both societal and individual life safety risk tolerable risk guidelines; however, there is a residual risk associated with Levee C. Levee C was screened from further evaluation due to being structurally superior and having no life safety risk associated with any of the potential failure modes associated with Levee C. Levee C was screened from further evaluation due to being structurally superior and having no life safety risk associated with any of the potential failure modes. However, there will still be residual risk associated with flood damages, since flood depths of 2 to 4 feet with overtopping would still exist within Levee C.

The recommended plan has addressed the risk for overtopping, but the risk still remains above tolerable risk guideline for life safety risk even though it is greatly reduced. Therefore, individuals and industry within Levee C should be informed that a threat still remains, and the Tulsa County Emergency Action Plan should be updated and also included in the Tulsa County Floodplain Management Plan. Life safety risk estimates are very sensitive to the evacuation response. If warning times are shorter or evacuation is limited, the number of people at risk would rise dramatically. For example, with changes in the mobilization rate, fatality estimates tripled.

Areas outside of the levee system will continue to face flood risk unless additional actions are taken outside of this project.

4.3 Risk and Uncertainty

A key piece of any analysis or project is the explicit acknowledgement and consideration for uncertainty. Uncertainty can be commonly divided into knowledge uncertainty and natural variability. For the most part knowledge uncertainty can be reduced with additional data gathering, analyses, or other analytical tools but natural variability can only be understood and not readily reduced. Uncertainties discussed in this section apply to all of the alternatives similarly and, therefore, none of these uncertainties would change the recommendation.

Key areas of risk and uncertainty identified in the study include: 1) cost uncertainty, 2) insufficient data regarding penetration along the levee system, 3) geotechnical uncertainty, 4) HTRW conditions, 5) utilities, 6) cultural resources, and 7) real estate.

1) Cost uncertainty is reflected in the contingency amounts indicated in Section 4.3 below. The TSP has a relatively high contingency (35% percent, which reflects uncertainty in the preliminary cost estimate and has the potential for scope and quantity growth during design.)
2) Insufficient data on penetrations (known and unknown) along the Levee System. Numbers could be higher or lower than available records show; and therefore, there is a risk of increased cost of project design and construction. The study team used historical information and has addressed each location identified and added contingency for unknown.
3) Geotechnical analyses took into account all available data; however, unforeseen subsurface conditions could impact original design assumptions. A risk assessment helped the team determine that most uncertainty was ascribed to overtopping and under and through seepage failure modes and progression of internal erosion.

4) There is an existing superfund site in Levee Area A and refinery in Levee Area C that has pipelines under and across the river into Levee Area B. This could lead to delays while conditions are investigated, and potentially add costs if remediation is required. Additional costs could include adjusting the design to avoid the contamination; however, the team does anticipate that any costs due to HTRW would not be substantial as this would be primarily be a sponsor cost to provide a clean environment to perform work.
5) There is also potential for additional utility relocations, as detailed investigations into underground utilities have not yet been completed. Utility relocations can result in schedule delays and cost increases. Uncertainty regarding utility relocations has been captured in the cost estimate contingencies.
6) Cultural Resource Surveys will be conducted in the project's Area of Potential Effect (APE) when appropriate. This survey effort will include evaluation of the Tulsa-West Tulsa Levees to determine whether they are eligible for listing in the National Register of Historic Places (NRHP). If it is determined that the levees are eligible for listing in the NRHP, or if other historic properties are identified during survey, USACE will work with the SHPO and other PA signatories to avoid, minimize, and mitigate any adverse effects, which may affect project design and costs. The likelihood of adverse effects to historic properties is equal for all of the final alternatives.
7) The Sponsor has existing real estate easements and encroachments to clear for the required clear zone of 15 feet beyond the toe of the levee. The Sponsor has a plan for acquiring these easements. In addition, the recommended plan would require purchase of construction easements. The PDT will start the real estate process early in PED to avoid schedule delays due to difficulties in real estate acquisition. To prioritize design efforts, due to risk with real estate, Levee B will be evaluated both from a geotechnical capacity and hydraulics capacity first to ensure the proper land and acquisition evaluations.

Chapter 2.0 discusses assumptions related to the no-action alternative (future without project condition) and uncertainty regarding potential environmental impacts. Similar analyses are found throughout the main report and in the appendices.

4.4 Cost Sharing

Based on FY 2019 price levels, estimated project cost (first cost) totals $ 159.7 M, and the estimated federal and non-federal shares are $ 93.1 M and $ 66.6 M, respectively, which equates to 65 percent federal and 35 percent non-federal based on cost sharing provisions of WRDA1986 (

Table 4-1). In addition, the Bipartisan Act of 2018 allows non-federal sponsors a period of 30 years from the date of project completion (or completion of a separable element) to pay their cash contribution of a cost share. The estimated value of LERRDs has not yet been determined. For more information about LERRDs, please see the Real Estate Plan Appendix F.

Table 4-1: Cost Estimate for TSP

Cost Account and Project Features	Federal Share	Non-Federal Share	Project First Cost
	FY2019 Price Level		
Alternative 1E – TSP	65%	35%	
Total Correction & Reconstruction	$ 65.2 M	$ 35.1 M	$ 100.3 M
Planning, Engineering & Design	$ 18.6M	$ 10.0 M	$ 28.6 M
Construction Management	$ 8.2 M	$ 4.4 M	$ 12.6 M
Subtotal:	***$ 92.0 M***	***$ 49.5 M***	***$ 141.5 M***
Charles Page Floodway Structure			
Total Correction & Reconstruction	$ 773,600	$ 416,500	$ 1.2 M
Planning, Engineering & Design	$ 220,000	$ 139,000	$ 339,000
Construction Management	$ 97,000	$ 52,000	$ 149,000
Subtotal:	***$ 1.1 M***	***$ 600,000***	***$ 1.7 M***
Contaminate Soil Disposal[1] **(100 percent NFS cost)**	0%	100%	
Total Soil Disposal	$ 0	$ 11.7 M	$11.7 M
Planning, Engineering & Design	$ 0	$ 3.3 M	$ 3.3 M
Construction Management	$ 0	$ 1.5 M	$ 1.5 M
Subtotal:	***$ 0***	***$ 16.5 M***	***$ 16.5 M***
LERRD[2] (100 percent NFS cost)			
01 Lands and Damages			TBD
02 Relocations			TBD
LERRD Subtotal			**TBD**
Project First Cost	**$ 93.1 M[3]**	**$ 66.6 M[3]**	**$ 159.7 M[3]**

1 100% Local Share

2 LERRD costs have not yet been assessed.

3 Preliminary cost share based on uncertified cost and do not include costs for 01 or 02 account.

Note: There may be slight differences due to rounding.

4.5 OMRR&R

Operation, maintenance, repair, replacement and rehabilitation (OMRR&R) for the recommended plan include, but are not limited to:

- Frequent mowing, weed control and vegetation removal of seepage berms;
- Utility usage, electrical rehabilitation, mechanical inspection and mechanical rehabilitation for pump station nos. 1 through 7;
- Pump tests and mechanical rehabilitation for pumps 1 through 7;

- Toe drain cleaning and video inspection every 5 to 7 years; or after flood events initiating flow;
- Riprap along Levee B will require herbicide applications.
- Video inspections of conduits;
- Replacement of pump motors every 25 to 30 years; and,
- Operation and maintenance of the detention structure will also be the responsibility of Tulsa County.

Order of magnitude estimates of annualized OMRR&R totals $400,000 per annum. This figure will be revised as additional data are available. Pending project approval, the Tulsa District will update an OMRR&R Manual with the non-federal sponsor.

4.6 Implementation Plan

Construction of the recommended plan requires no additional Congressional authorization. Public Law 115-123 provides, “that a project that is studied using Supplemental investigations funds is eligible for implementation using Construction funds provided in that Act if the Secretary determines that the project is technically feasible, economically, justified, and environmentally acceptable.“ Implementation of the project depends on approval of this report, appropriation of sufficient Federal design and construction funding, and Project Partnership Agreement executed between the U.S. Army Corps of Engineers and the non-Federal sponsor.

4.7 Implementation Schedule

A Project schedule has been developed based upon the assumption that this Supplemental Report will be approved by or before September 30, 2020. The Project schedule sequences design and construction activities to allow immediate execution of the plan beginning in FY2021. The development of this schedule assumes Federal funding is available in the years required and that the real estate actions are completed on schedule.

The recommended schedule reflects the information currently available and the current departmental policies governing execution of projects. It does not reflect program and budgeting priorities inherent in either the formulation of a national civil works construction program or the perspective of higher review levels within the Executive Branch. Consequently, the schedule recommended may be modified before it is transmitted to higher authority for implementation funding. Under current plans, advertisement and award of the first item of construction for the project is scheduled in FY2021 and FY2022, pending funding. Assuming funding availability, construction completion is planned for FY2024.

4.8 Sponsor Support

The non-Federal Sponsor is fully supportive of the recommended plan.

4.9 Sponsor Requirements

1) Provide a minimum of 35 percent, as further specified below:

a) Required to pay 35 percent of design costs allocated by the Government to flood risk management in accordance with the terms of a design agreement after completion of work, which can be amortized over 30 years as provided for in the Bipartisan Act of 2018; and

b) Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the flood risk management features;

2) Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefor, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

3) Not less than once each year, inform affected interests of the extent of protection afforded by the flood risk management features;

4) Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

5) Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the flood risk management features;

6) Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood risk management features;

7) Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the flood risk management features afford, hinder operation and maintenance of the project, or interfere with the project's proper function;

8) Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-

4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

9) For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

10) Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

11) Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

12) Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

13) Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c et seq.);

14) Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or

under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

15) Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

16) Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

17) Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

CHAPTER 5: ENVIRONMENTAL CONSEQUENCES

5.1 Alternative Analysis

Numerous alternatives were formulated, evaluated, and screened as described in Chapter 3. The final array includes Alternatives 1E, 3B, 5, and 6 (No Action Alternative). Chapter 5 of this report assessed each alternative in the final array against the No Action Alternative. Alternative 1E was identified as the TSP.

The TSP consists of constructing filter berms and rebuilding existing degraded toe drains on the landside of levees A and B. The TSP also includes a cutoff wall along the Superfund site that intersects Levee A, and Levee B would require a landside impervious surface such as concrete or riprap to prevent severe erosion during river overtopping. Filtered berms without toe drains would be built on the tieback section of Levee B, and a filtered berm would be installed into the existing floodwall at the Charles Page floodway structure. Pump stations 1 through 7 would be rebuilt to address interior flooding. Chapter 4 – Recommended Plan describes the TSP in greater detail.

5.2 Significance Criteria and Impact Characterization Scale

In accordance with Council on Environmental Quality (CEQ) regulations and implementing guidance, impacts are evaluated in terms of their significance. The term “significant,” as defined in 40 CFR 1508.27, part of the CEQ regulations for implementing NEPA, requires consideration of both context and intensity. Context means that the significance of an action must be analyzed in several settings, such as society as a whole (human, national); the affected region; the affected interests; and the locality. Significance varies with the setting of the TSP. For instance, in the case of a site-specific action, significance would usually depend on the effects on the locale rather than on the world as a whole.

Intensity refers to the severity of impact with regard to the above ratings (minor through significant). Factors contributing to the evaluation of the intensity of an impact include, but are not limited to:

- The balance of beneficial and adverse impacts, in a situation where an action has both;
- The degree to which the action affects public health or safety;
- The unique characteristics of the geographic area where the action is proposed, such as proximity to parklands, historic or cultural resources, wetlands, prime farmlands, wild and scenic rivers, and ecologically critical areas;
- The degree to which the effects on the quality of the human environment are likely to be controversial;
- The degree to which the effects of the action on the quality of the human environment are likely to be highly uncertain or involve unique or unknown risks;

- The degree to which the action might establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration;
- Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action “temporary” or by breaking it down into small component parts;
- The degree to which the action might adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the NRHP or might cause loss or destruction of significant scientific, cultural, or historic resources;
- The degree to which the action might adversely affect an endangered or threatened species or habitat that has been determined to be critical under the Endangered Species Act of 1973; and;
- Whether the action threatens a violation of Federal, state, or local law or requirements imposed for the protection of the environment.

Impacts are characterized by their relative magnitude. Adverse or beneficial impacts that are significant are the highest levels of impacts. Conversely, negligible adverse or negligible beneficial effects are the lowest level of impacts. Nine descriptions are used to characterize the level of impacts. In order of degree of increasing impact they are:

- Significant Adverse Effect
- Moderate Adverse Effect
- Minor Adverse Effect
- Negligible Adverse Effect
- No Impact or Negligible Effect
- Negligible Beneficial Effect
- Minor Beneficial Effect
- Moderate Beneficial Effect
- Significant Beneficial Effect

Identifying potential impacts requires consideration of the context and degree of impacts. When feasible, distinctions are made between short and long-term impacts, negligible and significant impacts, and negative and positive impacts. A negligible impact may be inconsequential or unlikely, whereas a significant impact would have more pronounced or severe consequences that are generally adverse in nature. If the current condition of a resource would improve or an undesirable impact would lessen, the impact is beneficial. A no impact determination means an action does not noticeably affect a given resource. Cumulative impacts are those that are likely to occur over long periods, or those that result from a combination of expected impacts of two or more unrelated actions.

5.3 Air Quality

5.3.1 Tentatively Selected Plan (TSP)

The construction of the TSP would have short-term, minor to moderate, adverse impacts on air quality for the Tulsa area. The increase of construction activity would result in the temporary

increase of air pollution in the immediate surrounding area as total construction time is expected to be less than two years. The narrow construction area of the filtered berms and small size of the detention ponds would limit exhaust emissions. Limited space is available for heavy equipment that can be used at any given time. This would limit spikes in greenhouse gas emissions (GHG) emissions throughout construction. Change in attainment status for all pollutants in the Tulsa area is not expected as a result of the TSP. No conformity determination would be required as the Tulsa area is currently in attainment status for air quality.

5.3.2 Alternative 3B

The construction of the Alternative 3B would have short-term, minor to moderate adverse impacts on air quality for the Tulsa area. The increase of construction activity would result in the temporary increase of air pollution in the immediate surrounding area as total construction time is expected to be 2-4 years. The work would excavate the centerline of levees A and B, not including the stretch of levee adjacent to the superfund site, and construct a cutoff into the made of the levee. The narrow construction area of the cutoff wall and small size of the detention ponds would limit exhaust emissions, however additional construction time would be needed as the concrete cutoff wall would require more time to complete. Limited space is available for heavy equipment that can be used at any given time. This would limit spikes in GHG emissions throughout construction. Change in attainment status for all pollutants in the Tulsa area is not expected as a result of Alternative 3B. No conformity determination would be required as the Tulsa area currently in attainment status for air quality.

5.3.3 Alternative 5

Alternative 5 entails buying out residential buildings, terminating utilities to each structure, and removing the structure itself and any above ground utilities. According to this report's Economics Appendix (Appendix C), 2,266 residential structures, and six multi-family buildings exist within Levees A and B. The buying out and removal of all residential structures, their utilities, and other infrastructure would have short term, moderate to major, adverse impacts to air quality in the area.

5.3.4 No Action Alternative

The construction of various other ongoing projects in the Tulsa area would be expected to have minor to moderate adverse impacts on air quality from heavy equipment exhaust emissions. Although, this impact would be temporary, and lessen over time as projects are completed. The ability to construct the large projects planned in the Tulsa area such as the Arkansas River Corridor Ecosystem Restoration measures, improvements to Zink Dam, Jenks Dam, and others at the same time would likely be difficult due to available funding and work force. As such, the emissions associated with construction activities would likely also be spread out over a longer period, further reducing the concentration of exhaust emissions.

No long-term change in air quality is expected in the Tulsa area in the No Action Alternative as newer, cleaner forms of construction and transportation are developed and used on a wider scale.

5.4 Climate and Climate Change

5.4.1 Tentatively Selected Plan

No impacts on climate or climate change are expected from the construction of the TSP. While GHG emissions from construction would contribute to climate change, they would represent a negligible fraction of all emissions influencing climate change. As such, no change from the predicted climate change described in Part 2 would occur from the TSP.

5.4.2 Alternative 3B

No impacts on climate or climate change are expected from the construction of Alternative 3B. While GHG emissions from construction would contribute to climate change, they would represent a negligible fraction of all emissions influencing climate change. As such, no change from the predicted climate change described in Part 2 would occur from Alternative 3B.

5.4.3 Alternative 5

No impacts on climate or climate change are expected from the construction of Alternative 5. While GHG emissions from construction would contribute to climate change, they would represent a negligible fraction of all emissions influencing climate change. As such, no change from the predicted climate change described in Part 2 would occur from Alternative 5.

5.4.4 No Action Alternative

No impacts to climate and climate change are expected in the No Action Alternative. While emissions occurring in the Tulsa area contribute to climate change, they represent a negligible fraction of all emissions. As such, no change from the predicted climate change described in Part 2 would occur in the No Action Alternative without large scale efforts to curb emissions.

5.5 Water Resources (Surface Water, Ground Water, and Water Quality)

5.5.1 Tentatively Selected Plan

A 404(b)1 analysis was completed and submitted to the Oklahoma Department of Environmental Quality for their review and comments towards receiving Water Quality Certification. The 404(b)1 analysis further examines impacts to Waters of the United States (WOTUS) rule (see Appendix E 4). No impacts to WOTUS are expected from the construction of filter berms along the levees or rebuilding of the pump stations as all work would be constructed away from surface water and wetlands on the landside of the levees.

Adjacent to the Superfund site located within Levee A, an impervious blanket would be constructed on the riverside of the levee along with a cutoff wall. All required best management

practices (BMPs) would be in place to prevent erosion and sedimentation of waterways, and prevent accidental fuel spills from contaminating water. Avoidance and minimization BMPs are included in Appendix E4.

Approximately 1,833 linear feet of Harlow Creek and its creek banks would be excavated during the construction of the detention ponds. Approximately 2.9 million cubic feet would be excavated when including the upland areas within the nine acres of the detention area. Between 5 to 8 feet of depth would be excavated to contain the 1 percent annual chance exceedance (ACE) event and relieve flood load on the Levee B tieback The creek bed would be widened and bank slopes reduced to create the detention volume. Post-construction, the creek would flow in its existing path. The adjacent banks and detention area would be planted with native vegetation, mostly grasses, with infrequent mowing occurring.

To reduce impacts to less than significant, the appropriate number of credits would be purchased from a local stream mitigation bank. The current stream habitat quality is being evaluated with resource agencies to determine the number of credits needed. Based on the reach of Harlow Creek within the detention areas, existing habitat quality is expected to be moderate at best as the banks are mowed right up to the water edge and are adjacent to, or bound by culverts passing under local roadways.

The existing culverts would continue to meter downstream flow with the TSP. No changes in flow, turbidity, quality, or total surface area of water resources are expected with the TSP, however during flood events turbidity would likely increase, as it does now, as sediment and flood debris move through the creek.

Ground water properties would not be expected to change with the TSP as flow waters would be detained for less than 24 hours post flood event.

5.5.2 Alternative 3B

Impacts to water resources associated Alternative 3B would be the same as the TSP as it also includes the same detention ponds in the same location.

5.5.3 Alternative 5

Impacts to water resources in Alternative 5 would be the same as those in the No Action Alternative.

5.5.4 No Action Alternative

No change in current conditions of ground and surface waters are expected in the No Action Alternative. Local and state authorities continue to monitor and implement water conservation and water quality efforts to maintain or enhance existing resources.

5.6 Hydrology and Floodplains

5.6.1 Tentatively Selected Plan

Approximately 1,833 linear feet of Harlow Creek and its creek banks would be excavated during the construction of the detention ponds. Approximately 2.9 million cubic feet would be excavated when including the upland areas within the nine acres of detention area. Between 5 to 8 foot of depth would be excavated to contain the 1 percent ACE event and relieve flood load on the Levee B tieback The creek bed would be widened and bank slopes reduced to create the detention volume. Post-construction, the creek would flow in its existing path. Negligible to minor, permanent widening of the floodplain would occur within the excavated areas. Harlow Creek would continue to be influenced and limited by the existing levees, roads, bridges, and culverts. The existing culverts and Harlow Creek would continue to convey water as they do currently during periods of normal flow and small rain events.

Along the Arkansas River, no change in hydrology or floodplains would occur as improvements to the levees and pump stations would not alter channel capacity, floodplain size or access, or the flow water in the area.

Appendix B contains more information regarding the reduction of flood loading achieved by the detention ponds during flood events.

5.6.2 Alternative 3B

Impacts to hydrology and floodplains associated with Alternative 3B would be the same as the TSP as it includes the same detention ponds in the same location.

5.6.3 Alternative 5

Impacts to hydrology and floodplains in Alternative 5 would be the same as those in the No Action Alternative.

5.6.4 No Action Alternative

The hydrology and floodplains that exist today would persist into the future as in the No Action Alternative.

5.7 Levees

5.7.1 Tentatively Selected Plan

The levee improvements in the TSP would improve their ability hold flood waters and increase life safety during large flood events. More efficient interior drainage would occur as the toe drains and pump station functions would be restored.

The general location, shape, maintenance of ground cover, and aesthetic of the existing levees would experience negligible to minor changes as the filtered berm would stay in the existing footprint. The Sponsor is required to clear up any encroachments to the existing clear zone of 15 feet from the toe of the levee, pursuant to their latest Inspection Report and SWIF Plan.

Areas of the levees where impervious blankets would be constructed would sustain moderate changes in appearance as the rock, riprap, or concrete feature would stand out from the rest of the grass line levees.

Additional details regarding the increased performance are in Appendix A of this report.

5.7.2 Alternative 3B

The performance of the levees in Alternative 3B would be similar to the TSP.

The general location, shape, maintenance of ground cover, and aesthetic of the existing levees would experience negligible to minor changes, as the cutoff wall would not change the levee footprint. Some aesthetic change would occur as the top of the levee would likely change from a grass lined feature to a concrete or other hard surface. Areas of the levees where impervious blankets would be constructed would sustain moderate changes in appearance as the rock, riprap, or concrete feature would stand out from the rest of the grass line levees.

5.7.3 Alternative 5

Impacts to the levees in Alternative 5 would be the same as those in the No Action Alternative. Although with the residences removed, they would protect primarily businesses and other remaining infrastructure.

5.7.4 No Action Alternative

The levees that exist today would persist into the future as in the No Action Alternative. Although as noted in Appendices A, B, and D, continued flood risk to life and property would exist during large flood events.

5.8 Aquatic Resources

5.8.1 Tentatively Selected Plan

A 404(b)1 analysis was completed and submitted to the Oklahoma Department of Environmental Quality for their review and comments towards receiving Water Quality Certification. The 404(b)1 analysis further examines impacts to WOTUS. (See Appendix E 4). No impacts to WOTUS are expected from the construction of filter berms along the levees or rebuilding of the pump stations as all work would be constructed away from surface water and wetlands on the landside of the levees.

Adjacent to the Superfund site located within Levee A, an impervious blanket would be constructed on the riverside of the levee along with a cutoff wall. All required BMPs would be in place to prevent erosion and sedimentation of waterways, and prevent accidental fuel spills from contaminating water. Avoidance and minimization BMPs are included in Appendix E4.

Approximately 1,833 linear feet of Harlow Creek and its creek banks would be excavated during the construction of the detention ponds. Approximately 2.9 million cubic feet would be

excavated when including the upland areas within the nine acres of detention area. Between 5 to 8 foot of depth would be excavated to contain the 1 percent ACE event and relieve flood load on the Levee B tieback The creek bed would be widened and bank slopes reduced to create the detention volume. Post-construction, the creek would flow in its existing path. The adjacent banks and detention area would be planted with native vegetation, mostly grasses, with infrequent mowing occurring.

While no change in net stream length would occur, a semi-permanent to permanent loss of stream habitat quality would occur with the construction of the detention ponds.

To reduce impacts to less than significant, the appropriate number of credits would be purchased from a local stream mitigation bank. The current stream habitat quality is being evaluated with resource agencies to determine the number of credits needed. Based on the reach of Harlow Creek within the detention areas, existing habitat quality is expected to be moderate at best as the banks are mowed up to the water edge and are adjacent to, or bound by culverts passing under local roadways.

The existing culverts would continue to meter downstream flow with the TSP. No changes in flow, turbidity, quality, or total surface area of water resources are expected with the TSP, however during flood events turbidity would likely increase, as it does now, as sediment and flood debris move through the creek.

5.8.2 Alternative 3B

Impacts to aquatic resources in Alternative 5 would be the same as those in the No Action Alternative.

5.8.3 Alternative 5

Impacts to aquatic resources in Alternative 5 would be the same as those in the No Action Alternative.

5.8.4 No Action Alternative

The aquatic resources that exist today would persist into the future as in the No Action Alternative.

5.9 Natural Resources

5.9.1 Tentatively Selected Plan

Relatively few areas of natural resources occur within or adjacent to the landside of the levee footprints. Although a semi-continuous, narrow riparian forest corridor exists on the Arkansas River side of the levees. Resources on the riverside of the levees will remain almost completely untouched as the majority of the TSP will be constructed on the landside of the levees, with exception to the riverside construction opposite of the Superfund site.

Temporary, indirect disturbance to wildlife in the immediate area would occur from construction noise and visual disruptions.

Removal of small pockets of upland forest and individual trees may be necessary for the construction of the TSP. The largest would be roughly 1.88 acres of upland forest where the downstream detention pond would be built. Tree removal would occur outside of migratory bird and bat breeding season. Minor adverse impacts to the natural communities would occur from the removal of trees. The Arkansas River riparian corridor and other adjacent trees in the area would provide habitat for displaced birds, insects, and small rodents that likely use the area.

Opposite of the Superfund site, the riverside bank is mostly maintained grass outside of a very narrow strip of vegetation along the bank of the Arkansas River. The maintained grass area is expected to be sufficient for the riverside impervious blanket and cutoff wall. These riverside features would avoid adverse impacts to riparian forest, and the wildlife that use them, while also avoiding impacts to the remaining soil contaminates on the land side of the levee.

No riparian forest habitat has been identified that would be removed and require compensatory mitigation. If later identified, any riparian forest to be removed would be offset by the purchase of mitigation credits from local mitigation banks.

Temporary loss of stream habitat and fish communities may occur in Harlow Creek during the construction of the detention ponds. Coordination with resource agencies is ongoing to plan for relocations of any fish or amphibians that could occupy Harlow Creek before construction. After construction, fish and amphibian communities are expected to recolonize the area from nearby upstream and downstream habitats. During flooding, the larger flooded area of the detention ponds may provide short term foraging areas for water birds. The detention area would be replanted with native grasses, mowed only when necessary to maintain its flood risk purpose but never lower than 8 inches, and no longer be able to be developed for other uses. The detention ponds would become pseudo-refuge areas with native grasses. Negligible to minor long-term benefits may occur.

5.9.2 Alternative 3B

Impacts to natural resources in Alternative 3B would be the same as those in the TSP. Although fewer upland trees may be removed as the construction would primarily take place from the top of the levee.

5.9.3 Alternative 5

Impacts to natural resources in Alternative 5 would be the same as those in the No Action Alternative. Depending on the land use change, long-term benefits could be realized to natural resources as residential disturbances associated with cars, pets, noise, and lights would be removed and replaced with natural cover.

5.9.4 No Action Alternative

The natural resources that exist today would persist into the future as in the No Action Alternative.

5.10 Threatened and Endangered Species

5.10.1 Tentatively Selected Plan

The USACE has determined that the construction and operation of the TSP will have no effect to the least tern, piping plover, red knot, whooping crane, northern long-eared bat, and the rattlesnake master borer moth.

Piping plover, red knot, whooping crane, and the rattlesnake master borer moth are not expected to occur in the study area.

The riparian corridor buffer between construction activities and the Arkansas River avoids impacts to nesting and foraging least terns. To avoid impacts to the northern long-eared bat, tree removal will occur outside of their pup season, which occurs from late May to late July.

USACE has determined that the construction and operation of the TSP, particularly the detention ponds, may affect, and are likely to adversely affect the American burying beetle (ABB). A biological assessment has been prepared, and submitted to the USFWS Oklahoma Ecological Services Office as part of a request for formal consultation under the Endangered Species Act. Up to nearly nine acres of ABB habitat would be semi-permanently removed in the excavation of the detention ponds.

To reduce impacts to the ABB, onsite conservation measures within the detention ponds include replanting the area with native grasses, allowing the grass height within the detention ponds to remain at least 8 inches tall, and limit mowing and other ground disturbances to a minimum. The purchase of credits from an ABB conservation bank will reduce the impacts to the species to less than significant. During the PED phase, USACE will conduct USFWS approved ABB surveys to confirm ABB presence. If no ABB are detected, USFWS will be consulted to reevaluate mitigation needs.

Bald eagles utilize the Arkansas River Corridor for roosting, nesting, and foraging. While the construction of the TSP is not expected to have direct take of bald eagles, indirect impacts to nests may occur. To comply with the Bald and Golden Eagle Protection Act, bald eagle surveys will be conducted and coordinated with the USFWS Oklahoma Ecological Services Office and USFWS Southwest Region Migratory Bird Office during the PED phase. This information will be used to develop impact avoidance and minimization plans and if necessary, obtain a bald eagle take permit prior to any construction occurring.

5.10.2 Alternative 3B

Impacts to protected species in Alternative 3B would be the same as those in the TSP.

5.10.3 Alternative 5

The removal of residences and subsequent land use change to natural land cover may provide beneficial impacts to the ABB and the northern long-eared bat through habitat expansion.

5.10.4 No Action Alternative

Existing protected species and their habitats would persist into the future as in the No Action Alternative.

5.11 Cultural Resources

5.11.1 Tentatively Selected Plan

Potential impacts to cultural resources include disturbance of known or previously undiscovered archaeological material at the detention pond and filtered berm sites, as well as access routes, and construction laydown areas. If it is determined that the levees themselves are eligible for listing in the National Register of Historic Places (NRHP), construction impacts to the levees could constitute an adverse effect under Section 106 of the National Historic Preservation Act (NHPA) of 1966. In addition to direct impacts that may be caused by construction of the TSP, changes to the viewshed (the geographical area visible from a location) of any historic properties determined to be present may also occur. A draft programmatic agreement (PA), which has been developed to avoid, minimize, and mitigate potential adverse effects in accordance with 36 CFR 800.14 is included in Appendix I; the executed final PA will be included in the final feasibility report.

5.11.2 Alternative 3B

Impacts to cultural resources in Alternative 3B would be the similar to those described for the TSP, including impacts to the existing levee system, which has not been evaluated for NRHP eligibility, and potential impacts to previously unknown archaeological resources. It is anticipated that construction of the cutoff wall would require a significantly larger work area than the TSP, and thus, has a greater potential to adversely affect previously unknown historic properties.

5.11.3 Alternative 5

While little to no new ground disturbance would occur in Alternative 5, the removal of some residential properties may include properties that are eligible for listing in the NRHP. One NRHP-eligible structure, the Sand Springs Power Plant, is located behind Levee A; this and any previously unknown historic properties and would be susceptible to increased flood risk under Alternative 5.

5.11.4 No Action Alternative

The No Action Alternative will not change conditions from the existing condition. The study area will continue to have multiple cultural resources and high potential resource sites.

5.12 Land Use, Recreation, and Transportation

5.12.1 Tentatively Selected Plan

Temporary, adverse impacts to residential land use, recreation, and transportation may take place near construction areas, construction easements, along haul routes, and in open areas such as parking lots of maintained fields. The levee-protected areas would be subject to temporary use of construction equipment for up to two years. While construction would be temporary in any given area, road closures and the use of privately owned areas may be needed to complete construction. Every effort will be made to design TSP features that will avoid the use of private property. When unavoidable, temporary construction easements will be obtained for temporary use of private land. In some areas, private property may be temporarily removed and then replaced upon construction completion. Railroad tracks occur at the base of the eastern edge of Levee B. These tracks may be temporarily removed and then replaced once construction is complete.

5.12.2 Alternative 3B

Impacts to land use, recreation, and transportation in Alternative 3B would be similar to those in the TSP. Although fewer private properties may be disturbed near the levees because the construction would primarily take place from the top of the levee.

5.12.3 Alternative 5

Alternative 5 entails buying out residential buildings, terminating utilities to each structure, and removing the structure itself and any above ground utilities. According to Economics Appendix (Appendix C), 2,266 residential structures, and 6 multi-family buildings exist within Levees A and B. The buying out and removal of all residential structures, their utilities, and other infrastructure would have permanent, moderate to significant, adverse or beneficial impacts to land use depending on the viewpoints of local residents.

In the place of residential areas, natural areas of forest or grasslands would likely be maintained with little to no amenities or options for human occupancy.

5.12.4 No Action Alternative

The No Action Alternative will not change land use, recreation, or transportation of the existing condition. Although future large flood events may have temporary to permanent adverse impacts on land use, recreation, and transportation in the area.

5.13 Socioeconomics

5.13.1 Tentatively Selected Plan

The enhanced protection of life and property within the levee-protected areas would not be expected to have adverse impacts on socioeconomics of the area. Depending on future flood event severity, negligible to major benefits would occur to property owners and life safety as a result of the TSP.

5.13.2 Alternative 3B

Impacts to socioeconomics in Alternative 3B would be the same as those in the TSP, although the TSP is expected to provide those benefits at a lower cost to the local community.

5.13.3 Alternative 5

Alternative 5 entails buying out residential buildings, terminating utilities to each structure, and removing the structure itself and any above ground utilities. According to Economics Appendix (Appendix C), 2,266 residential structures, and 6 multi-family buildings exist within Levees A and B. The buying out and removal of all residential structures, their utilities, and other infrastructure would have permanent, moderate to significant, adverse or beneficial impacts to land use depending on the viewpoints of local residents.

In the place of residential areas, natural areas of forest or grasslands would likely be maintained with little to no amenities or options for human occupancy.

Executive Order 12898, entitled “Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations (1994),” addresses disproportionate human health and environmental impacts that a project or plan may have on minority or low-income communities. Thus, the environmental effects of a plan on such communities including Native American populations must be disclosed, and agencies must evaluate projects to ensure that proposed actions do not disproportionally impact minority or low income communities. If such impacts are identified, appropriate mitigation measures must be implemented.

To determine if a project has a disproportionate effect on potential environmental justice communities (i.e., minority or low-income population), the demographics of an affected population within the vicinity of a project must be considered in the context of the overall region. Guidance from the Council on Environmental Quality (CEQ) states that, “minority populations should be identified where either: (1) the minority population of the affected areas exceeds 50 percent, or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis (CEQ 1997).”

Table 6 in the Economic Appendix displays U. S. Census Bureau data summarizing racial characteristics of areas next to plan construction sites. The purpose is to analyze whether the demographics of the affected area differ in the context of the broader region; and if so, do differences meet CEQ criteria for an Environmental Justice community. Based on the analysis, it does not appear that minorities in the study area are disproportionately affected; however, the study area may qualify as a low-income population.

5.13.4 No Action Alternative

The No Action Alternative will not change the economics of the existing condition. Although future large flood events may have temporary to permanent adverse effects on economics in the area.

5.14 Utilities

5.14.1 Tentatively Selected Plan

Some utilities including water, electricity, sewer, telecommunications, etc. may be temporarily or permanently relocated, but not cut off entirely, in order to construct the TSP. Temporary, adverse impacts to utilities may occur near construction areas, construction easements, along haul routes, and in open areas such as parking lots of maintained fields as utilities are relocated. During utility relocations, scheduled temporary outages may be needed. These temporary outages would be announced to the public in advance so adequate preparations could be made.

5.14.2 Alternative 3B

Impacts to utilities in Alternative 3B would be similar to those in the TS, although fewer utilities may be disturbed near the levees as the construction would primarily take place from on top of the levee.

5.14.3 Alternative 5

Alternative 5 entails buying out residential buildings, terminating utilities to each structure, and removing the structure itself and any above ground utilities. According to Economics Appendix (Appendix C), 2,266 residential structures, and 6 multi-family buildings exist within Levees A and B. The buying out and removal of all residential structures, their utilities, and other infrastructure would have permanent, moderate to significant, adverse or beneficial impacts to land use depending on the viewpoints of local residents.

In the place of residential areas, natural areas of forest or grasslands would likely be maintained with little to no amenities or options for human occupancy.

5.14.4 No Action Alternative

The No Action Alternative will not change utilities from the existing condition. Although future large flood events may have temporary to permanent adverse effects on utilities in the area.

5.15 Health and Safety

5.15.1 Tentatively Selected Plan

The primary purpose of the TSP is to increase life safety during large flood events through filtered berm improvements on Levees A and B to keep rising Arkansas River waters out of the levee-protected area. The reconstruction of pump stations 1 through 7 would help abate interior drainage issues by pumping water from the landside to the riverside of the levees. These measures would allow more time for evacuations, mobilization of flood fighting resources, and flood fight response during severe flood events.

Sanitary conditions are expected to be improved during and after flood events with the reconstruction of the pump stations. Ponding water on the landside of the levees would be mitigated by increased efficiency of working pumps to move the water out of neighborhoods and in to the Arkansas River.

The increased time for life saving measures, including evacuations ahead of flooding is further described in models used for analysis in Appendices B and C.

5.15.2 Alternative 3B

Health and Safety impacts in Alternative 3B would be similar to those in the TSP, although the benefits would come at extra monetary cost.

5.15.3 Alternative 5

Life safety would almost be completely addressed by removing all residences from the levee-protected areas. The only remaining life risk would be to businesses within the same area.

5.15.4 No Action Alternative

The No Action Alternative will not affect health and safety from the existing condition, although future large flood events would continue to threaten the safety and health of those living within the levee protected areas.

5.16 Hazardous, Toxic, and Radioactive Waste (HTRW)

5.16.1 Tentatively Selected Plan

The construction of the TSP, particularly the riverside impervious blanket and cutoff wall, could directly affect the Sand Springs Petrochemical Complex, or vice versa. The chemical complex was designated a Superfund site in 1986. It was removed from the National Priority List in 2000.

While multiple cleanup efforts have been carried out at the site, there is a low potential to encounter previously undiscovered hazardous waste through construction excavation. As a precaution, the non-Federal Sponsor (Tulsa County Drainage District 12) would conduct an environmental site investigation as part of the proposed action to confirm that no undiscovered hazardous waste sources exist in proximity to the construction area. Additionally, BMPs would be implemented to prevent movement of substances if they should be unexpectedly encountered. As part of the BMPs, the Complex would be avoided and not be disturbed, excavated, or used for laydown, parking or stockpiling during construction.

Potential for negligible short-term impact from the spill of fuel or oil associated with construction equipment exists.

5.16.2 Alternative 3B

The HTRW impacts in Alternative 3B would be similar to those in the TSP. The cutoff wall in Alternative 3B could require slight changes in the levee footprint to avoid HTRW issues.

5.16.3 Alternative 5

The HTRW effects would almost be completely avoided by removing all residences from the levee-protected areas. The only remaining contaminant risk would be from the demolition of residences and utilities.

5.16.4 No Action Alternative

The No Action Alternative will not change the HTRW presence from the existing condition. Although future large flood events would continue to threaten the safety and health of those living within the levee protected areas.

5.17 Topography, Geology, and Soils

5.17.1 Tentatively Selected Plan

Approximately 1,833 linear feet of Harlow Creek and its creek banks would be excavated during the construction of the detention ponds. Approximately 2.9 million cubic feet would be excavated when including the upland areas within the nine acres of detention area. Between 5 to 8 foot of depth would be excavated to contain the 1 percent ACE event and relieve flood load on the Levee B tieback The creek bed would be widened and bank slopes reduced to create the detention volume. Post-construction, the creek would flow in its existing path. The adjacent banks and detention area would be planted with native vegetation, mostly grasses, with infrequent mowing occurring. Minor permanent adverse impacts to soils and topography would occur with the TSP through excavation of soils.

5.17.2 Alternative 3B

Impacts to topography, geology, and soils in Alternative 3B would be similar to those in the TSP, although they would come at extra monetary cost.

5.17.3 Alternative 5

Alternative 5 entails buying out residential buildings, terminating utilities to each structure, and removing the structure itself and any above ground utilities. According to Economics Appendix (Appendix C), 2,266 residential structures, and 6 multi-family buildings exist within Levees A and B. The buying out and removal of all residential structures, their utilities, and other infrastructure would have permanent, moderate to significant, adverse or beneficial impacts to land use depending on the viewpoints of local residents.

In the place of residential areas, natural areas of forest or grasslands would likely be maintained with little to no amenities or options for human occupancy. Temporary adverse impacts to surface soils would occur in Alternative 5. Long-term beneficial impacts to soil conservation would occur in Alternative 5 as the previously residential areas would become naturally vegetated.

5.17.4 No Action Alternative

The No Action Alternative will not change health and safety risks from the existing condition. Future large flood events would continue to threaten the safety and health of those living within the levee protected areas.

5.18 Cumulative Impacts

Potentially, the most severe environmental degradation does not result from the direct effects of any particular action, but from the combination of effects of multiple, independent actions over time. As defined in the Code of Federal Regulations (CFR), Title 40 CFR 1508.7 (CEQ Regulations), a cumulative effect is the “impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.”

Some authorities contend that most environmental effects can be seen as cumulative because almost all systems have already been modified. Principles of cumulative effects analysis, as described in the CEQ guide Considering Cumulative Effects under NEPA, are:

- Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions.
- Cumulative effects are the total effects, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (Federal, non-Federal, or private) has taken the actions.
- Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected.
- It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.
- Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries.
- Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects.
- Cumulative effects may last for many years beyond the life of the action that caused the effects.
- Each affected resource, ecosystem, and human community must be analyzed in terms of the capacity to accommodate additional effects, based on its own time and space parameters.

See Table 5-1 for a comparison of cumulative impacts.

According to the CEQ regulations a cumulative effect is defined as:

> *"The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions." (40 CFR §1508.7)*

Principles of cumulative effects analysis are described in the CEQ guide "Considering Cumulative Effects under the National Environmental Policy Act." For this analysis, cumulative effects are examined in terms of how the Recommended Action could affect downstream resources through interaction with other past, present, and reasonably foreseeable future actions. CEQ guidance on cumulative effects analysis states:

> *"For cumulative effects analysis to help the decision-maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to affected parties." (40 CFR 1508.7)*

The TSP has the potential for cumulative effects (with past, present, and reasonably foreseeable future projects) on land use, water resources, the socioeconomic environment, biological resources including protected species, and recreation. The cumulative effects assessment is limited to projects reasonably foreseeable through 2025 within the study areas for various resources described in the Part 5. The geographical boundaries for cumulative effects analysis are limited to those areas within and adjacent to the levee protected areas.

5.19 Past, Present, and Reasonably Foreseeable Projects within the TWT Levees Study Area

Adjacent to Levee A, the primary feature of the Arkansas River Corridor is a pool structure at river mile 530 of the Arkansas River. This structure would span the Arkansas River and reregulate river flows to increase the minimum river flow, expand riverine habitat, and improve overall habitat conditions in the Arkansas River.

Zink Dam is an existing low water dam adjacent to Levee C. Plans and efforts are underway to raise and rehabilitate the dam to improve river recreation opportunities.

Table 5-1: Comparison of Cumulative Impacts

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Arkansas River (O&M)	Since the 1960s, Keystone Dam and hydropower production have affected the river corridor flows. USACE operates and manages the Keystone Lake and Dam.	USACE operates and manages the Keystone Lake and Dam for the purpose of flood control, water supply, hydroelectric power generation, navigation, fish, and wildlife.	No change from existing conditions.	No change from existing conditions
Air Quality	General deterioration of air quality due to increases in human populations and industry. Improvements as a result of implementation of legislation.	Improved air quality due to regulations, public outreach, education and improved available and affordable control technology.	There would be temporary, short term, minor impacts due to emissions during construction of the other projects.	Implementing the proposed project would include minor short-term adverse effects on air emissions due to construction activities. Minor additive effects may occur if the projects are constructed simultaneously
Climate	Global warming trend beginning in the 1800s. Increase in GHG emissions increasing during the industrial revolution.	Warming trend and GHG emissions are continuing.	There would be temporary, short term, minor impacts due to GHG emissions during construction of the other projects.	Implementing the proposed project would have temporary, short term, minor impacts due to GHG emissions during construction that could affect climate change and would be additive with other projects in the corridor.

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Water Resources Open Water Groundwater Water Quality	Fluctuating water levels due to Keystone Dam operations and seasonal flows. The impoundment of Arkansas River and the influence of Keystone Dam have altered the natural conditions of once uncontrolled prairie river. Sands in the river wash down to the Zink Lake area. Construction of flood control levees along west and east bank of Arkansas River corridor in Tulsa. Degraded water quality due to human and industrial activity and reduced volume of water within the study area. Reduced riverine habitats	Continued degradation of riverine habitats within the study area from reduced flows and flow extremes. Reduced availability of riverine habitats. Continued degradation of water quality from increased human activity and disturbances within the watershed. Reduction in the downstream sediment supply below Keystone Dam. Released sands continue to accumulate above Zink Dam. Bank erosion and the disappearance of mid-channel bars as water released from Keystone Dam scours the channel bed and banks to re-establish equilibrium between flow and sediment transport Maintenance of existing flood control infrastructure. Water quality standards meet beneficial uses requirements.	Improved ecosystem in the ARC as a result of the ARC ER study.	Implementing the other low water dam projects within ARC, the long-term benefits would be additive with other projects to water resources if the operations of the other low water dams are coordinated through an adaptive management. This would improve the daily flows and attenuate the extreme flow variability which is a primary driver for overall impacts within the Arkansas River Acreages of open water would increase. Impacts to groundwater would be considered localized and negligible as ground water gradients changes would be minimal. Implementing the proposed action would have negligible impacts to water resources.

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Hydrology and Floodplains	The impoundment of Arkansas River and the influence of Keystone Dam have altered the natural flow conditions within the study area. Daily flows are greatly reduced and experience extreme fluctuations. The changes in the flow regime have led to deteriorated water quality, bank erosion, and loss of habitats for wildlife. Sediment starvation has occurred from sediment loads being trapped behind Keystone and Zink dams reducing riverine sandbar creation. Floodplains have been impacted from erosive scour during extreme flows and colonization of non-native, invasive plant species such as Johnson grass and salt cedar. No changes to floodplain storage.	The seasonal and operational fluctuations of the Arkansas River below the Keystone Dam continue to degrade ecosystems within the study area. Sediment starvation downstream of Keystone and Zink dams continues. Continued bank erosion and the disappearance of mid-channel bars as water released from Keystone Dam scours the channel bed and banks to re-establish equilibrium between flow and sediment transport. Continued colonization of floodplain habitats by invasive plant species. No changes to floodplain storage.	Improved ecosystem in the ARC as a result of the ARC ER study.	Releases from pool structure would augment river flow over weekends when there are no hydropower releases. Implementing the other low water dam projects within ARC, the operational procedures and benefits would be via adaptive management of the low water dams. The ecosystem within the study area would realize long-term positive impacts from the increase and attenuation of the flow regime. Water quality would improve from increases in water volumes and stabilization of wetland communities. No impacts to floodplains are expected as the proposed plan would be designed to not impact adversely impact floodplains.

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Vegetation and Habitat Wetlands	Wetland habitat acreages within study area reduced and disconnected to other habitats due to reductions in flow regime. Wetlands destabilized due to flow fluctuations, which has selected for early successional, emergent marsh habitat types.	Reduced wetland habitat acreage and connectivity to other habitats. Available wetland habitats dominated by early successional emergent marsh types due to decreased stability in study area.	Improved ecosystem in the ARC as a result of the ARC ER study.	Substantial increase in riverine habitats from the expansion and restoration of 3,735 acres of riverine habitat by flow regime measure. Increase in riverine habitats and connectivity throughout the study from the increased flow regime. The proposed action would have negligible impacts on vegetation and habitat.
Riverine Sand Bars	Sand bar habitat formation reduced from sediment starvation in reach downstream of Keystone Dam. Sand bar habitats destabilized from extreme fluctuations in flow regime. Vegetated sand bars being colonized by invasive plant species.	Ongoing reduction in stabile riverine sand bar habitat in the reach downstream of Keystone Dam from sediment starvation and extreme fluctuations in the flow regime. Continued establishment of invasive plant species.		
Open Water	Reduction in riverine habitat acreages and connection to other habitats from reduced flow regime	Reduced riverine habitat acreage and connectivity to other habitats.		
Biological Resources (Fish and Wildlife)	Reduced abundance of native wildlife species within the study area from the reduction in nursery (wetlands, open water) and foraging habitats (wetlands, riverine sand bars, and open water). Impediments to migratory fish passage and larval/egg transport from Keystone and Zink dams. Poor development of aquatic food webs which provide food sources for larger wildlife and listed species.	Continued reduced abundance of wildlife within study area due to reduced habitat availability and connectivity.	Improved ecosystem in the ARC as a result of the ARC ER study.	Maintaining any flow in the river would improve water quality and fish habitat. Releases from pool structure would augment river flow over weekends when there are no hydropower releases. Negligible impacts on biological resources would occur from the proposed action.

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Threatened and Endangered Species	Un-vegetated riverine sand bar habitat within the study area has supported a viable interior Least Tern population and suitable nesting habitat. Loss of riverine sand bar habitat from sediment starvation has reduced available nesting habitat downstream of Keystone and Zink Dams. Extreme fluctuations in flow regime wash away low elevation nests, eggs, and chicks. Increased predation on eggs and chicks from land bridging of nesting habitats with upland habitats. Prey species such as small fishes reduced in abundance with in study area due to reduced flow regime. Other listed species either present in low abundance due to preferred habitats not being present (American Burying Beetle), or are migratory incidental species (Piping Plover, Red Knot), or are minimally dependent on habitats found within the study area (Northern long-eared Bat, rattlesnake master borer moth).	Least Tern populations stable within the study area but likely reduced from historic populations due to reduced nesting habitats and continued impacts to nests from flow fluctuations and predation.	Improved ecosystem in the ARC as a result of the ARC ER study.	Moderate long-term benefit to Least Tern populations from increase in abundance of habitats, stabilized flow regime reducing impacts to nests, eggs, and chicks, increased surface water habitats promoting reduced land bridging and predation, and an increase in abundance of prey species from increased habitat availability. Negligible to minor, adverse impacts to the American burying beetle. Although conservation efforts and mitigation requirements have led to the proposed downgrading of the American burying beetle from endangered to threatened by the USFWS.
Cultural and Archeological	Federal undertakings are subject to the NHPA Section 106 process and other laws pertaining to cultural resources.	Human activities as well as natural processes can potentially degrade or destroy cultural resources.	No change from existing conditions.	The proposed action could adversely impact known as well as unknown cultural resources

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Land Use, Recreation and Transportation	Conversion of a prairie and sandstone hill landscape over time for agricultural, transportation and commercial / industrial uses. Introduction of recreation activities within corridor with the addition of trails, amenities, parks, lookouts, recreational clubs, and entertainment facilities. An increase in non-water based transportation infrastructure in the form of roads, railroads, and bridges.	Ongoing re-development and enhancement of downstream recreation opportunities and transportation improvements within the Tulsa area	Land use development in the corridor would likely continue but would not be clustered along the riverfront in Sand Springs. Continued development of recreation opportunities in leased and private lands in a more piecemeal fashion. Other infrastructure projects in the corridor would include downstream transportation improvements and the addition of other low water dams.	The proposed action would have negligible, long-term impacts on land use, recreation, and transportation.
Socioeconomics	Increasing populations and commercial development in the communities along the Arkansas River corridor.	Population centers and economic development continue along the river corridor.	No change from existing conditions.	The proposed action would have negligible, long-term impacts on socioeconomics.
Visual Aesthetics	Human population growth, development, and other human activities have the potential to destroy, enhance, or preserve visual resources. Historical transportation and industrial development activities adjacent to the river have negatively affected the visual and aesthetics of the river corridor.	Development activities continue to detract from the visual and esthetic resources of the corridor though efforts are ongoing to improve downstream conditions.	No change from existing conditions.	The proposed action would have negligible, long-term impacts on visual aesthetics.

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Utilities	Development of extensive utility infrastructure throughout the corridor. Increased investment in water supply, wastewater, energy, communication and stormwater control facilities and structures in populated areas along the Arkansas River corridor.	Ongoing operation and maintenance of existing utilities and infrastructure within the Tulsa area	No change from existing conditions.	The proposed action would have negligible impacts on utilities.
Health and Safety	Degradation and destabilization of the river banks due to natural processes and human development without appropriate best management practices.	Increased human activity along unstable river banks pose recreational health and safety issues to the public.	No change from existing conditions.	Moderate, beneficial impacts from the proposed plan, in combination with lessons learned from recent flooding events, and local planning efforts.
Hazardous Materials or Toxic Substances	Degradation of some areas untreated and uncontrolled discharges, especially in urbanized and/or industrialized areas with improvements as a result of implementation of legislation. Former EPA Superfund Site located near the proposed pool structure location at RM 530.	Hazardous materials use and transportation are a regulated activity, thus monitored and permitted only when impacts are minimized and BMPs implemented. Site has been removed from the NPL in 2000.	No change from existing conditions.	No change from existing conditions. Risk of encountering HTRW is unknown –may range from nothing, to materials that require special handling/disposal to large scale clean up prior to construction.

Resource	Historic Conditions	Existing Conditions	Future Without Project (No Action Alternative)	Cumulative Effects (Comparison of Future with Action Alternative Impacts)
Geology, Seismicity, and Soils	Sediment continuity from the upstream reach has been interrupted by Keystone Dam and the flow regime has been modified. The channel downstream of Keystone Dam has experienced incision and bank erosion as it has been scoured of sediment to regain the sediment load of the river that is trapped upstream in Keystone Lake. The river banks have continued to erode due to sandy soils. The channel downstream of Keystone Dam has experienced incision and bank erosion as it has been scoured of sediment to regain the sediment load of the river that is trapped upstream in Keystone Lake.	Widespread bank erosion has continued throughout the river corridor and along the project area.	Erosion would likely continue until the banks of the channel are armored along the entire reach below Keystone Dam.	No change from existing conditions.

CHAPTER 6: ENVIRONMENTAL COMPLIANCE

Table 6-1 presents the status of compliance with all environmental laws and regulations for the proposed action. Additional information regarding specific compliance actions is below.

Table 6-1: Relationship of Plan to Environmental Protection Statutes and Other Environmental Requirements

Policies	Compliance of Plan
Public Laws	
Archeological and Historic Preservation Act, 1974, as amended	In Progress
Archeological Resources Protection Act, 1979, as amended	In Progress
Clean Air Act, 1977, as amended*	In Progress
Clean Water Act, 1972, as amended*	In Progress
Coastal Zone Management Act, 1972, as amended	Not Applicable
Endangered Species Act, 1973, as amended*	In Progress
Farmland Protection Policy Act	Not Applicable
Fish and Wildlife Coordination Act, 1958, as amended*	In Progress
Magnuson Fisheries Conservation and Management Act	Not Applicable
Migratory Bird Treaty Act, 1918, as amended*	In Progress
National Environmental Policy Act, 1969, as amended	In Progress
Rivers and Harbors Act, 1899	Not Applicable
Wild and Scenic Rivers Act, as amended	Not Applicable
Native American Graves Protection and Repatriation Act, 1990	In Progress
National Historic Preservation Act, 1966, as amended	In Progress
Executive Orders	
Environmental Justice (E.O. 12898)*	In Progress
Protection of Children (E.O. 13045)	In Progress
Flood Plain Management (E.O. 11988)	In Progress
Protection of Wetlands (E.O. 11990)	In Progress
Invasive Species (E.O. 13112)*	In Progress
Migratory Birds (E.O. 13186)*	In Progress
Others	
FAA Advisory Circular 150-5200-33*	Complete

6.1 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) requires Federal agencies that are impounding, diverting, channelizing, controlling, or modifying the waters of any stream or other body of water to consult with the USFWS and appropriate State fish and game agency to ensure that wildlife conservation receives equal consideration in the development of such projects. From the initial stages of this study the USFWS, ODWC, and ODEQ were asked for input and/or concerns regarding the study.

All agencies provided comments throughout the planning process. USFWS provided valuable information regarding existing habitat conditions and habitat mitigation options.

A draft Fish and Wildlife Coordination Act Report (See Appendix E2) describing potential impacts, avoidance measures, and mitigation has been prepared for the TWT Study.

6.2 Endangered Species Act

Oklahoma is home to several Federally listed species and unique habitats like karst features in the Ozark Highlands and native prairies. Through informal consultation with the USFWS Oklahoma Ecological Services, USACE determined the TSP would have No Effect on all species except for the American Burying Beetle (ABB). USACE determined the construction of the detention ponds may affect, and is likely to adversely affect the ABB. Therefore, USACE has requested Formal Consultation with and submitted a Biological Assessment to the USFWS Oklahoma Ecological Services Office (See Appendix E3).

To reduce impacts to the ABB, onsite conservation measures within the detention ponds include replanting the area with native grasses, allowing the grass height within the detention ponds to remain at least 8 inches in height and limit mowing, and other ground disturbances, to a minimum. The purchase of 2.25 impacted acres worth of credits from an ABB conservation bank will be purchased prior to construction, if necessary. USACE will conduct USFWS approved ABB surveys to confirm ABB presence. If no ABB are detected, USFWS will be consulted with to reevaluate mitigation needs.

6.3 Bald and Golden Eagle Protection Act

The bald eagle will continue to be protected by the Bald and Golden Eagle Protection Act even though it has been delisted under the Endangered Species Act. This law, originally passed in 1940, provides for the protection of the bald eagle and the golden eagle (as amended in 1962) by prohibiting the take, possession, sale, purchase, barter, offer to sell, purchase or barter, transport, export or import, of any bald or golden eagle, alive or dead, including any part, nest, or egg, unless allowed by permit Bald Eagle sitting in tree (16 U.S.C. 668(a); 50 CFR 22). "Take" includes pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or

disturb (16 U.S.C. 668c; 50 CFR 22.3). The 1972 amendments increased civil penalties for violating provisions of the Act to a maximum fine of $5,000 or one year imprisonment with $10,000 or not more than two years in prison for a second conviction. Felony convictions carry a maximum fine of $250,000 or two years of imprisonment. The fine doubles for an organization. Rewards are provided for information leading to arrest and conviction for violation of the Act.

Bald eagles utilize the Arkansas River Corridor for roosting, nesting, and foraging. While the construction of the TSP is not anticipated to have direct take of bald eagles, indirect impacts to nests may occur. To comply with the Bald and Golden Eagle Protection Act, bald eagle surveys will be conducted and coordinated with the USFWS Oklahoma Ecological Services Office and USFWS Southwest Region Migratory Bird Office during the PED phase. This information will be used to develop impact avoidance and minimization plans and if necessary, obtain a bald eagle take permit prior to any construction occurring.

6.4 Clean Air Act

Federal agencies are required by this Act to review all air emissions resulting from federally funded projects or permits to insure conformity with the State Implementation Plans in non-attainment areas. The Tulsa area is currently in attainment for all air emissions within the project area, the construction of the TSP is not expected to alter that status; therefore, the TSP would be in compliance with the Clean Air Act and no General Conformity Determination would be required.

6.5 Clean Water Act

USACE, under direction from Congress, regulates the discharge of dredged and fill material into all waters of the United States, including wetlands. Although USACE does not issue itself permits for construction activities that would affect waters of the United States, USACE must meet the legal requirements of the Act. A 404(b)(1) analysis was conducted for the TWT Study. Approximately 1,833 linear feet of Harlow Creek, including the creek bed and banks would be reshaped during detention pond construction. These losses would be offset by the purchase of a minimal number of stream credits from mitigation banks in the region. The study team is still coordinating with USFWS, ODEQ, and ODWC to determine the number of required credits and costs.

No net loss of waters of the United States would occur under the TSP. The excavation of the detention ponds would result in a total of approximately 2,901,664 cubic feet of fill being removed from these mostly upland sites down and into Harlow Creek. Upon construction completion, Harlow Creek would flow as it does now in the same footprint as it down now. ODEQ was provided a copy of the 404(b)(1) analysis for review as part of the State Water Quality Certification process under Section 401 of the Federal Clean Water Act to ensure the proposed project supports water quality standards (See Appendix E4).

The construction activities that disturb upland areas (land above Section 404 jurisdictional waters) are subject to the National Pollutant Discharge Elimination System (NPDES) requirements of Section 402(p) of the Clean Water Act.

In Oklahoma, ODEQ is the permitting authority and administers the NPDES. Operators of construction activities that disturb 5 or more acres must prepare a Storm Water Pollution Prevention Plan (SWPPP), submit a Notice of Intent to ODEQ and obtain authorization under OKR10, conduct onsite posting and periodic self-inspection, and follow and maintain the requirements of the SWPPP. During construction, the operator shall assure that measures are taken to control erosion, reduce litter and sediment carried offsite (silt fences, hay bales, sediment retention ponds, litter pick-up, etc.), promptly clean-up accidental spills, utilize best management practices (BMPs) onsite, and stabilize the site against erosion before completion.

6.6 Section 106 of the National Historic Preservation Act

Under the National Historic Preservation Act, federal agencies must “take into account the effects of their undertakings on historic properties” [(36 CFR 800.1(a)]. Because USACE cannot fully determine the effects of the undertaking on historic properties at this time, USACE, Oklahoma State Historic Preservation Officer (SHPO), and the non-federal sponsor have developed a programmatic agreement (PA) to resolve adverse effects to historic properties. A copy of the draft PA is included in Appendix I.

In accordance with 36 CFR 800.6(1), USACE has notified the Advisory Council on Historic Preservation of the intent to develop a PA. During the feasibility study, USACE has conducted background research, consulted with the Oklahoma SHPO, and invited Federally-recognized Native American tribes to consult on the project and to participate in the development of the PA. To date, two of the three tribes consulted, the Muscogee (Creek) Nation and the Osage Nation, have stated that they have important cultural resources in the vicinity of the project and thus have been invited to participate in the PA as a concurring party. Consultation with the SHPO, OAS, and federally recognized tribes is ongoing and will continue throughout the feasibility, design, and construction phases of the project.

USACE hosted a consultation webinar with the SHPO to provide a project overview and discuss the development of a PA. The SHPO provided comments on the draft PA; all comments received were incorporated into the current draft. Consultation and coordination with the SHPO is ongoing and will continue throughout project design and construction.

6.7 Executive Order 13112 – Invasive Species

EO 13112 recognizes the significant contribution native species make to the well-being of the Nation's natural environment and directs Federal agencies to take preventive and responsive action to the threat of the invasion of non-native plants and wildlife species in the United States.

This EO establishes processes to deal with invasive species and among other items, establishes that Federal agencies "will not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless, pursuant to guidelines that it has prescribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions."

The required operation and maintenance of the TSP by the non-Federal implementation sponsor during long-term management of that area would keep the negative influence of non-native invasive plants at a minimum. The proposed project would be in compliance with EO 13112 by actively monitoring and managing non-native invasive species.

6.8 Executive Order 11988 – Floodplain Management

EO 11988 was enacted May 24, 1977, in furtherance of the National Environment Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), the National Flood Insurance Act of 1968, as amended (42 U.S.C. 4001 et seq.), and the Flood Disaster Protection Act of 1973 (Public Law 93-234, 87 Star. 975). The purpose of the EO was to avoid, to the extent possible, the long and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative.

The order states that each agency shall provide and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for: (1) acquiring, managing, and disposing of Federal lands and facilities; (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities. The TSP, inherit as a flood risk management project, would be designed to ensure that the combination of all measures proposed would not result in a decrease in the floodplain capacity and or increase in flood risk to the study area. The TSP would be in compliance with EO 11988.

ER 1165-2-26 sets forth general policy and guidance for USACE implementation of EO 11988, as is pertains to the planning, design, and construction of Civil Works projects. The objective of this EO is to avoid, to the extent possible, long and short-term adverse impacts associated with the occupancy and modification of the base flood plain.

Due to the nature and authorization of this flood risk management study and the proposed measures' functions, there were no other practical alternatives to locating the proposed project in the base flood plain. The design and operation of each measure will minimize hazard and risk associated with flood and human safety while reducing flood risk and damages in the downstream base flood plain.

New developments would require the necessary planning and permits to avoid impacts to the environment and the base flood plain.

6.9 Executive Order 13186 – Migratory Birds

The importance of migratory non-game birds to the nation is embodied in numerous laws, executive orders, and partnerships. The Fish and Wildlife Conservation Act of 1980 demonstrates the Federal commitment to conservation of non-game species. Amendments to the Act adopted in 1988 and 1989 direct the USFWS to undertake activities to research and conserve migratory non-game birds. EO 13186 directs Federal agencies to promote the conservation of migratory bird populations, including restoring and enhancing habitat. Migratory Non-game Birds of Management Concern is a list maintained by the USFWS. The list helps fulfill a primary goal of the USFWS to conserve avian diversity in North America. Additionally, the USFWS Migratory Bird Plan is a draft strategic plan to strengthen and guide the agency's Migratory Bird Program.

The TSP requires the permanent conversion of potential migratory bird habitat, upland forest, to detention ponds and maintained areas of the levees. Most migratory species nest between early April and mid-August, some nesting activity may occur during all months of the year depending on location. Some eagles, owls, and finches may nest in mid-winter. Tree clearing would be conducted outside of nesting season to avoid impacts to nests, where practicable. Any tree clearing that occurs during the nesting season will be coordinated with the USACE environmental staff, USFWS Oklahoma Ecological Services Office, and the USFWS Southwest Region Migratory Bird Office to ensure migratory bird impacts are minimized.

6.10 Executive Order 12898 – Environmental Justice

EO 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" dated February 11, 1994, requires all Federal agencies to identify and address disproportionately high and adverse effects of its programs, policies, and activities on minority and low-income populations. Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies. Data was compiled to assess the potential impacts to minority and low-income populations within the study area.

The TSP would better protect minority and low income populations within the land side of the levee from future flooding without relocating residents outside of the levee protected areas. No environmental justice concerns are anticipated and the TSP would be consistent with EO 12898.

6.11 Executive Order 13045 – Protection of Children

EO 13045 “Protection of Children from Environmental Health Risks” dated April 21, 1997 requires Federal agencies to identify and address the potential to generate disproportionately high environmental health and safety risks to children. This EO was prompted by the recognition that children, still undergoing physiological growth and development, are more sensitive to adverse environmental health and safety risks than adults.

Short-term impacts on the protection of children would be expected during construction in urbanized areas with children present. Numerous types of construction equipment such as backhoes, bulldozers, graders, and dump trucks, and other large construction equipment would be used throughout the duration of construction of the TSP. Because construction sites and equipment can be enticing to children, construction activity could create an increased safety risk.

Out of an abundance of caution, barriers and “No Trespassing” signs would be placed around construction sites to deter children from playing in these areas, and construction vehicles and equipment would be secured when not in use. Construction areas would be flagged or otherwise fenced, issues regarding Protection of Children are not anticipated.

6.12 Public and Agency Comments

On the evening of February 13, 2019, USACE and the non-Federal sponsor hosted a public scoping meeting in Sand Springs, Oklahoma at the Case Community Center. The public scoping meeting notice, Tulsa District social media posts, local media coverage, and comments received from public officials and entities can be found in Appendix E1.

In total, 17 comments were received. Five comments came from citizens in the Tulsa area. Their comments were supportive of levee improvements to protect against 500 year event and up to 1.6 million cfs release from Keystone Dam, and future levees study/construction between Downtown Tulsa and Bixby.

Ten comments from local city, county, non-profit, and Federal officials and congressman were received in support of levee improvements to protect against 500 year event and up to 1.6 million cfs release from Keystone Dam.

Southwestern Power Administration (SWPA) requested no alternative be selected that impacts daily hydropower operations. If construction in the Arkansas River is needed, SWPA requests 30-day advance notice prior to construction to alter operations.

Oklahoma Department of Environmental Quality requested that prior to construction, an NOI must be submitted to their office and authorization under OKR10 (construction stormwater) be obtained.

An open house style public information meeting, in conjunction with a 30 day public review period of the Draft Report, will be held on October 8, 2019 starting at 5:30 p.m. at the Case Community Center in Sand Springs. USACE and Tulsa County staff will be available to answer questions regarding the study, process, Tentatively Selected Plan, and draft report and EA. See Appendix E1 for public notices and further instructions on how to submit comments.

6.13 Study Coordination

Copies of agency coordination letters are presented in Appendix E1. Formal and informal coordination has been and will continue to be conducted with various Federal, state, local agencies and Federally recognized tribes.

6.14 Environmental Coordination

USFWS, ODEQ, SWPA, and ODWC have been, and will continue to be, involved in the study process. Further refinement of mitigation needs and further development of avoidance measures will rely heavily on their expertise regarding the protection of local natural resources.

6.15 Cultural Resources Coordination

A Programmatic Agreement is being developed and includes USACE, Tulsa County, Oklahoma SHPO, the Muscogee (Creek) Nation, and the Osage Nation. A draft of the Programmatic Agreement is included in Appendix I, and the final report will include the final, signed Programmatic Agreement.

6.16 Mitigation

The TSP will be designed with the smallest practicable footprint to still meet the requirements of the proposed project. All practicable means to avoid or minimize environmental impacts due to construction of the Tentatively Selected Plan will be considered.

Impact avoidance and minimization measures can be found in Appendix E2.

Compensatory mitigation for impacts to Federally threatened American Burying Beetle include the purchase of 2.25 impacted acres worth of credits from a regional conservation bank.

Compensatory mitigation for impacts to 1,883 linear feet of stream habitat in Harlow Creek will include the purchase of a minimal number of credits from a regional mitigation bank. The study team is still coordinating with USFWS and USACE Regulatory to determine the number of credits and costs.

6.17 Monitoring and Adaptive Management

The monitoring and adaptive management of the compensatory mitigation would be conducted by the operator of the mitigation and conservation banks.

CHAPTER 7: RECOMMENDATION

I recommend that the Tulsa and West Tulsa Levee, flood risk management project, be modified as generally described in this report as the recommended plan and with such modifications as may be advisable within statutory discretion be approved and remaining construction implementation completed. Implementation of these features will reduce the prior to overtopping risk of levee failure due to under and through seepage to tolerable levels.

The Total Project First Cost for the recommended plan is $159,688,000. Total average annual costs for the recommended plan is $ 6.8M (Federal discount rate of 2.875%, 50 year period of analysis). The recommended plan is a life safety reduction plan and is a NED exception plan.

The recommendations herein reflect the information available at the time and current Department of the Army policies governing the formulation of individual projects. They do not reflect programming and budgeting priorities inherent in the formulation of national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently the recommendations may be modified before they are approved for implementing funding. However, prior to approval, the state, Federal agencies and other parties will be advised of any modifications and afforded the opportunity to comment.

COLONEL SCOTT PRESTON
TULSA DISTRICT

CHAPTER 8: STUDY TEAM

8.1 Study Team

The following individuals are members of the study team and are primarily responsible for the preparation of this report:

- Bryan Taylor, Ph.D. – Project Manager
- Tacy Jensen – Lead Planner and Study Manager
- Ephraim Redden, P.E. – Engineering Technical Lead
- David Williams, P.E., Ph.D. – H&H Engineer
- Natalie Garrett - Planner
- Stuart Norvell – Economist
- Glenn Fulton – Economist
- Brandon Wadlington – Environmental
- David Gage - Environmental
- Leslie Crippen – Cultural Resources
- David S. Clark – HTRW
- Terry Rice – Cost Engineering
- Krista Berna – Real Estate
- Sara Goodeyon – Technical Editor
- Jordan Holmes, P.E. – Levee Safety Program Manager

8.2 Coordination and recipients

SWT has and will continue to coordinate with local, state and Federal agencies, tribes, the public and interested parties through public workshops, comment periods, email exchanges, social media and news releases. Comments received to date, can be found in Appendix E1.

A 30-day public comment period begins on September 16, 2019. The Draft Feasibility Report with Integrated EA and FONSI will be available for review during the public comment period at the following locations:

U.S. Army Corps of Engineers Tulsa District Office

Public Affairs Office

2488 East 81 st Street

Tulsa, Oklahoma 7 4137

Charles Page Library

551 East 4th Street

Sand Springs, Oklahoma 7 4063

Please address any comments by email at: TWT-Levees@usace.army.mil. Written comments may also be submitted at the public workshop.

An open house style public workshop, in conjunction with a 30 day public review period of the Draft Report, will be held on October 8, 2019 starting at 5:30 p.m. at the Case Community Center in Sand Springs.

See Appendix E1 for public notices and further instructions on how to submit comments. All other information about dates, documents and information can be found at the USACE Tulsa District website: https://www.swt.usace.army.mil/.

CHAPTER 9: REFERENCES

Avian Power Line Interaction Committee (APLIC), 2012. Suggested Practices for Avian Protection on Power Lines: The State of Art in 2012. Edison Electric Institute, APLIC, and the California Energy Commission. Washington, D.C. and Sacramento, CA.

American Ornithologists' Union (AOU). 1983. Check-list of North American Birds, 6th edition. Allen Press, Inc., Lawrence, Kansas. 877 pp.

Arnold, K., C. Coldren, and M. Fink. 1996. The Interaction Between Avian Predators and Golden-cheeked Warblers in Travis County, Texas. Sponsored by the Texas Department of Transportation. Research Report 1983-2, Study No. 7-1983, Texas Transportation Institute Texas A&M University, College Station, Texas.

Bio-West, Inc. 2012. Summary of 2011 sampling efforts related to Edwards Aquifer Authority Variable Flow Study under USFWS permit number TE037155-0. Round Rock, Texas.

Coldren, C.L., 1998. The Effect of Habitat Fragmentation on the Golden-cheeked Warbler. PhD Dissertation. Texas A&M University, College Station, Texas.

Brooks, Robert L. 2009. "Prehistoric Native Peoples," *The Encyclopedia of Oklahoma History and Culture*. https://www.okhistory.org/publications/enc/entry.php?entry=PR008.

Chang, Julie M. and Thomas M. Stanley. 2010. Geologic Map of the Sand Springs 7.5' Quadrangle, Osage and Tulsa Counties, Oklahoma. Oklahoma Geological Survey.

Emery, W.H.P. 1977. Current status of Texas wild-rice. *Southwestern Naturalist* 22:393-394.

Groeger, A. W., Brown P. F., Tietjen T. E., and Kelsey T. C. 1997. Water quality of the San Marcos River. *Texas Journal of Science* 49:279-294.

Evans, Monty. 2017. Oklahoma Economic Indicators. Issued by the Oklahoma Employment Security Commission. Accessed July 25, 2017. https://www.ok.gov/oesc_web/documents/lmiEconIndPub.pdf

Gates, Eddie Faye. 2004. The Oklahoma Commission to Study the Tulsa Race Riot of 1921. *Harvard. Black Letter Law Journal.* Vol. 20, 2004.

Guyton, W. F. and Associates. 1979. *Geohydrology of Comal, San Marcos, and Hueco springs*. Texas Department of Water Resources, Report 234 Handbook of Texas Online 2012.

Hammontree, S.E., Mabe, J.A., and Kennedy, J.H. 2012. Habitat Requirements of the Golden Orb (*Quadrula aurea*). Final Report for Texas Water Development Board and Texas Parks and Wildlife Department. TWDB Contract Nop. 0904830970.

Horne, F. R. and S. McIntosh. 1979. Factors influencing distribution of mussels in the Blanco River of central Texas. *The Nautilus* 94:119-133.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater Mussels of Texas. Texas Parks and Wildlife Press: Austin, Texas. 218 pp.

Howells, R. G. 2002. *Freshwater mussels (Unionidae) of the pimpleback complex (Quadrula spp.) in Texas.* Texas Parks and Wildlife Management Data Series 197. Austin, Texas.36 pp.

Howells, R. 2006. Statewide freshwater mussel survey. Final report. State Wildlife Grants Program. Texas Parks and Wildlife Department, Austin.

Howells, R. G. 2010. *Texas pimpleback (Quadrula petrina): summary of selected biological and ecological data for Texas*. BioStudies, Kerrville, Texas. 17 pp. Hubbs and Peden 1969.

Hunt, Douglas A. 2004. Defining American Homelands: A Creek Nation Example, 1828-1907. *Journal of Cultural Geography*. Fall/Winter 2004. 21(1):19-43.

Karatayev, A. Y., and L. E. Burlakova. 2008. Distributional survey and habitat utilization of freshwater mussels. Texas Water Development Board

Lee, L (Fall2016) Do you Live in Flash Flood Alley? txH2O. Texas Water Resources Institute Alley http://twri.tamu.edu/publications/txh2o/fall-2016/do-you-live-in-flash-flood-alley/

Matthews, J.R. and C.J. Moseley (eds.). 1990. The Official World Wildlife Fund Guide to Endangered Species of North America. Volume 1. Plants, Mammals. xxiii + pp 1-560 + 33 pp. appendix + 6 pp. glossary + 16 pp. index. Volume 2. Birds, Reptiles, Amphibians, Fishes, Mussels, Crustaceans, Snails, Insects, and Arachnids. xiii + pp. 561-1180. Beacham Publications, Inc., Washington, D.C

Mens, M.J.P. (2015). System robustness analysis in support of flood and drought risk management. Delft, Netherlands. 161p.

Mens, M.J.P., Gilroy, K., and Williams, D. (2015). Developing system robustness analysis for drought risk management: an application on a water supply reservoir. Nat. Hazards Earth Syst. Sci. 15: 1933-1940.

Najvar, P. A. 2001. The effects of diel water quality fluctuations on reproduction and growth in the San Marcos salamander. M.S. thesis, Southwest Texas State University, San Marcos.

Nardone, Kathryn. 1967. Tulsa, Oklahoma: Some Aspects of Its Urban Settlement. *Proceedings of the Oklahoma Academy of Science.* Vol. 47. Pp. 378-381.

NatureServe. 2018A. Whooping Crane: Ecology Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Grus+americana

NatureServe 2018B. Golden-cheeked Warbler: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Dendroica+chrysoparia+

NatureServe 2018C. Golden Orb: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Quadrula+aurea

NatureServe 2018D. Texas Fatmucket: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Lampsilis+bracteata

NatureServe 2018E. Texas Fawnsfoot: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=truncilla+macrodon

NatureServe 2018F.Texas Pimpleback: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Quadrula+petrina

NatureServe 2018G. Comal Springs Dryopid Beetle: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Stygoparnus+comalensis

NatureServe. 2018H. Peck's Cave Amphipod: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Stygobromus+pecki

NatureServe. 2018I. Gray Bracted Twistflower: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Streptanthus+bracteatus

NatureServe. 2018J. Texas Wild Rice: Ecology & Life History. Available on the internet at: http://explorer.natureserve.org/servlet/NatureServe?searchName=Zizania+texana

National Oceanic Atmospheric Administration (NOAA). 2019. NOWData – NOAA Online Weather Data. New Braunfels Weather Forecast Office https://w2.weather.gov/climate/xmacis.php?wfo=ewx

Nelson, J. 1993. Population size, distribution, and life history of *Eurycea nana* in the San Marcos River. M.S. Thesis, Southwest TSU, San Marcos, Texas.

Odell, George H. 1999. The Organization of Labor at a Protohistoric Settlement in Oklahoma. *Journal of Field Archaeology.* Vol. 26, No. 4 (Winter 1999). Pp. 407-421.

OSUM. 2011. Texas pimpleback (*Quadrula petrina*) records. Bivalve Database, Division of Molluscs, Museum of Biological Diversity, Department of Evolution, Ecology, and

Organismal Biology. The Ohio State University, Columbus. Available online: http://www.biosci.ohio-State.edu/~molluscs/OSUM2

Poole, J.M. and D.E. Bowles. l999. Habitat characterization of Texas wild-rice (*Zizania texana* Hitchcock), an endangered aquatic macrophyte from the San Marcos River, TX, USA. *Aquatic Conserv: Mar. Freshwater Ecosystem* 9:291-301.

Poole, J. M. 2002. Historical distribution of Texas wild-rice (*Zizania texana*) from 1989 to 2001. Section 6 Final Report. Albuquerque, N. M.: U. S. Fish and Wildlife Service.

Qiao, L., Hong, Y., McPherson, R., Shafer, M., Gade, D., Williams, D., Chen, S., Lilly, D. (2014). Climate change and hydrological response in the trans-state Oologah Lake watershed – evaluating dynamically downscaled NARCCAP and statistically downscaled CMIP3 simulations with VIC model. Water Resour. Manage., 28(10): 3291-3305.

Randklev, C. R., B. Lundeen, and J. H. Kennedy. 2010. Unpublished museum records of rare freshwater mussels in Texas. University of North Texas, Denton.

Saunders, K.S., K.B. Mayes, T.A. Jurgensen, J.F. Trungale, L.J. Kleinsasser, K. Aziz, J.R. Fields, and R.E. Moss. 2001. *An evaluation of spring flows to support the Upper San Marcos River Spring ecosystem, Hays County, Texas*. River Studies Report No. 16. Resource Protection Division, Texas Parks and Wildlife Department, Austin, Texas.

Seal, U. S. and Ellis, S. (Eds.). 1997. Fountain Darter Working Group. Discussion Notes (Revised). Austin Texas, 19 November. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Silveus, W.A. 1933. *Texas grasses.* The Clegg Col, San Antonio, Texas. 782 pp.

SWCA Environmental Consultants (April 2007). Biological Assessment of the Proposed Construction and Operation of the Area 11 Flood Retarding Structure in Comal County, Texas. Prepared for the Federal Emergency Management Agency, Denton, Texas and U.S. Fish and Wildlife Service, Austin, Texas.

SWCA Environmental Consultants (April 2009). Comal County Regional Habitat Conservation Plan. Prepared for the Comal County, Texas, Comal County Commissioners Court.

Terrell, E.E., W.H.P. Emery, and H.E. Beatty. 1978. Observations on *Zizania texana* (Texas wild-rice), an endangered species. *Bulletin of the Torrey Botanical Club* 105:50-57.

TPWD. 2018A. San Marcos Salamander (*Eurycea nana*). Available on the internet at: https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/

TPWD. 2018B. Texas Blind Salamander (*Eurycea rathbuni*). Available on the internet at: https://tpwd.texas.gov/huntwild/wild/species/blindsal/

TPWD. 2018C. Fountain Darter (*Etheostoma fonticola*). Available on the internet at: https://tpwd.texas.gov/huntwild/wild/species/fdarter/

Tupa, D., W. Davis. 1976. Population dynamics of the San Marcos salamander, *Eurycea nana* Bishop. *The Texas Journal of Science*, 27:179-194.

USACE (2014). Utilization of Regional Climate Science Programs in Reservoir and Watershed Risk-Based Assessments.

USACE (1996). Risk-based analysis for flood damage reduction studies. EM 1110-2-1619.

USACE (2018). Guidance for incorporating climate change impacts to inland hydrology in civil works studies, designs, and projects. ECB 2018-14.

USFWS. 1991. Golden-Cheeked Warbler Recovery Plan.

USFWS. 1992. Golden-cheeked Warbler *(Dendroica chrysoparia)* Recovery Plan. Albuquerque, N.M. 88 pp.

U.S. Fish and Wildlife Service. 2007. National Bald Eagle Guidelines. U.S. Fish and Wildlife Service, Divisions of Endangered Species and Migratory Birds and State Programs, Washington, D.C. 25 pp.

U.S. Fish and Wildlife Service. 2009. Post-delisting Monitoring Plan for the Bald Eagle (Haliaeetus leucocephalus) in the Contiguous 48 States. U.S. Fish and Wildlife Service, Divisions of Endangered Species and Migratory Birds and State Programs, Midwest Regional Office, Twin Cities, Minnesota. 75 pp.

Vogel, Gregory. 2005. *A View from the Bottomlands: Physical and Social Landscapes and Late Prehistoric Mound Center in the Northern Caddo Area.* Dissertation on file, University of Arkansas.

Woods, A.J., Omernik, J.M., Butler, D.R., Ford, J.G., Henley, J.E., Hoagland, B.W., Arndt, D.S., and Moran, B.C. 2005. Ecoregions of Oklahoma (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey.